

# **U.S. Environmental Protection Agency**

## **DRAFT CONTAMINATED SEDIMENTS SCIENCE PLAN**

**Prepared for U.S. Environmental Protection Agency  
by members of the Contaminated Sediments Science Plan Workgroup,  
a group of U.S. EPA's Science Policy Council**

### **Principal Authors**

Elizabeth Lee Hofmann (Chair),  
OSWER

Thomas Armitage, OW

Bonnie Eleder, U.S. EPA Region 5

Steve Ells, OSWER

Patricia Erickson, ORD

Sharon Frey, OSWER

James Rowe, ORD

Marc Tuchman, GLNPO

Randall Wentsel, ORD

**Science Policy Council  
U.S. Environmental Protection Agency  
Washington, DC 20460**

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## ACKNOWLEDGMENTS

### Contributors

Elizabeth Beiring, OW

Edward Bender, ORD

David Bennett, OSWER

Scott Cieniawski, GLNPO

Kevin Garrahan, ORD

Scott Ireland, OW

Lorelei Kowalski, ORD

Jennifer Lenz, OSWER

## EXECUTIVE SUMMARY

In 2000, the United States Environmental Protection Agency's (U.S. EPA's) Science Policy Council (SPC) initiated the development of the Science Plan because contamination of sediments is a multi-faceted, cross-Agency issue which can benefit from a more comprehensive and higher level of coordination across U.S. EPA program and regional offices than what occurs at the program level. Extensive resources to address contaminated sediment problems are spent by a number of Agency program offices, including the Superfund Program (SF), Office of Water (OW), Office of Solid Waste (OSW), Great Lakes National Program Office (GLNPO), Office of Pollution Prevention and Toxic Substances (OPPTS), Office of Research and Development (ORD), and U.S. EPA Regional Offices.

The Contaminated Sediments Science Plan is the first formal example of an Agency science plan on a specific cross-Agency office- and region-wide activity. However, it follows in the footsteps of previous U.S. EPA initiatives, such as the *Mercury Action Plan* (U.S. EPA, 2001c), the *Action Plan for Beaches and Recreational Waters (Beach Action Plan)* (U.S. EPA, 1999a), and *A Multimedia Strategy for Priority Persistent, Bioaccumulative, and Toxic (PBT) Pollutants* (U.S. EPA, 1998a). These plans and strategies contain elements of both science plans and management action plans. The result of an effective science plan will be improved environmental decision-making which conserves both human and financial resources.

The Contaminated Sediments Science Plan has three goals to promote the vision of providing a strong scientific basis for addressing contaminated sediments:

1. Development and dissemination of tools and science necessary to address the management of contaminated sediments.
2. Enhancement of the level of coordination and communication of science activities dealing with contaminated sediments across the Agency.
3. Development of an effective, cost-efficient strategy to promote these scientific activities, including research.

The Science Plan is organized into four chapters. Chapter One discusses the goals, objectives, and how the Science Plan relates to the Agency's mandate. Chapter Two provides an overview of the contaminated sediment problems and issues across the Agency. The brief description of issues in Chapter Two is meant to provide an introduction to the discussion of contaminated sediment issues, as well as the overall context for the more detailed discussion of specific science needs given in Chapter Three.

Chapter Three, along with U.S. EPA's contaminated sediment science activities' database (Appendix A), is the data collection and analysis section of the Science Plan. It

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documents the current Contaminated Sediment Science Activities ongoing within the Agency, and places these activities within the context of Agency goals. Significant data gaps and uncertainties in methodology/assessment procedures are identified. Finally, it proposes science activities to fill those data gaps and resolve related issues.

Chapter Four provides the key recommendations for future Agency science activities, including research, based on the discussion in Chapter Three. For each recommendation, critical U.S. EPA partners and the immediate or long-term nature of the science activity are proposed. The workgroup did not constrain the recommendations to fit within available resources. Instead, the recommendations are a comprehensive list that U.S. EPA organizations can consider when balancing resource allocations across competing high-priority needs.

Key scientific questions, which are given below, were developed for each major topic in order to focus discussions on scientific needs and to identify recommended science activities to address these questions.

*Key Scientific Questions:*

**Sediment Site Characterization:** What physical, chemical and biological methods best characterize sediments and assess sediment quality?

**Exposure Assessment:** What are the primary exposure pathways to humans and wildlife from contaminants in sediments and how can we reduce uncertainty in quantifying and modeling the degree of exposure?

**Human Health Effects and Risk Assessment:** What are the risks associated with exposure to contaminants in sediments through direct and indirect pathways?

**Ecological Effects and Risk Assessment:** What are the risks associated with exposure to contaminants in sediments to wildlife species and aquatic communities?

**Sediment Remediation:** What sediment remedial technology or combination of technologies is available to effectively remediate sites?

**Baseline, Remediation, and Post-remediation Monitoring:** What types of monitoring are needed to ensure that the implemented remedy meets remedial performance goals and does not cause unacceptable short-term effects?

**Risk Communication and Community Involvement:** How can we provide communities with more meaningful involvement in the contaminated sediments cleanup process?

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**Information Management and Exchange Activities:** How do we improve information management and exchange activities on contaminated sediments across the Agency?

Table E-1 summarizes the key recommendations, the critical U.S. EPA partners, and the immediate or long-term nature of the science needs.

**Table E-1. Summary of Key Recommendations, Time Frame for Implementation, and Suggested Critical Partners**

Recommendations
<p><b>A. Sediment Site Characterization</b></p> <p><i>Immediate Time Frame</i></p> <p>A.1 Conduct a workshop to develop a consistent approach to collecting sediment physical property data for use in evaluating sediment stability. (OERR, ORD, U.S. EPA Regions)</p> <p><i>Longer Time Frame</i></p> <p>A.2 Develop more sensitive, low-cost laboratory methods for detecting sediment contaminants, and real-time or near real-time chemical sensors for use in the field. (ORD, OERR, GLNPO)</p> <p>A.3 Develop U.S. EPA-approved methods with lower detection limits for analysis of bioaccumulative contaminants of concern in fish tissue. (ORD, OERR, OW, U.S. EPA Regions)</p> <p>A.4 Develop methods for analyzing emerging endocrine disruptors, including alkylphenol ethoxylates (APEs) and their metabolites. (ORD)</p>
<p><b>B. Exposure Assessment</b></p> <p><i>Immediate Time Frame</i></p> <p>B.1 Develop a tiered framework for assessing food web exposures. (ORD, OW, OERR, U.S. EPA Regions)</p> <p>B.2 Develop guidance and identify pilots for improving coordination between TMDL and remedial programs in waterways with contaminated sediments. (OW, OSWER, U.S. EPA Regions)</p> <p>B.3 Develop and advise on the use of the most valid contaminant fate and transport models that allow prediction of site-specific exposures in the future. (ORD, OERR, OW, U.S. EPA Regions)</p> <p>B.4 Develop a consistent approach to applying sediment stability data in transport modeling. (ORD, OERR, OW, U.S. EPA Regions)</p>

**C. Human Health Effects and Risk Assessment***Immediate Time Frame*

- C.1 Develop guidance for characterizing human health risks on a PCB congener basis. (ORD, OERR, U.S. EPA Regions)
- C.2 Develop sediment guidelines for bioaccumulative contaminants that are protective of human health via the fish ingestion pathway. (ORD, OERR, OW, U.S. EPA Regions)

*Longer Time Frame*

- C.3 Refine methods for estimating dermal exposures and risk. (ORD, OERR, U.S. EPA Regions)
- C.4 Evaluate the toxicity and reproductive effects of newly recognized contaminants, such as alkylphenol ethoxylates (APEs) and other endocrine disruptors and their metabolites on human health. (ORD)

**D. Ecological Effects and Risk Assessment***Immediate Time Frame*

- D.1 Develop sediment guidelines to protect wildlife from food chain effects. (ORD, OERR, OW, U.S. EPA Regions)
- D.3 Develop guidance on how to interpret ecological sediment toxicity studies (lab or *in situ* caged studies); and how to interpret the significance of the results to site populations and communities. (OW, ORD, OERR, U.S. EPA Regions)
- D.4 Acquire data and develop criteria to use in balancing the long-term benefits from dredging vs. the shorter term effects on ecological receptors and their habitats. (ORD, OERR, U.S. EPA Regions)
- D.6 Continue developing and refining sediment toxicity testing methods. (ORD, OW, U.S. EPA Regions)
- D.7 Develop whole sediment toxicity identification evaluation procedures for a wide range of chemicals. (ORD, OW)

*Longer Time Frame*

- D.2 Develop additional tools for characterizing ecological risks. (ORD, U.S. EPA Regions, OW)
- D.5 Conduct field and laboratory studies to further validate and improve chemical-specific sediment quality guidelines. (OW, ORD)

**E. Sediment Remediation***Immediate Time Frame*

- E.1 Collect the necessary data and develop guidance for determining the conditions under which natural recovery can be considered a suitable remedial option. Such guidance would include: measurement protocols to assess the relative contribution of the various mechanisms for chemical releases from bed sediments (e.g., advection, bioturbation, diffusion, and resuspension), including mass transport of contaminants by large storm events; methodologies to quantify the uncertainties associated with natural recovery; and development of accepted measuring protocols to determine *in situ* chemical fluxes from sediments. (ORD, OERR, U.S. EPA Regions, GLNPO)
- E.2 Develop performance evaluations of various cap designs and cap placement methods and conduct post-cap monitoring to document performance. Continue to monitor ongoing capping projects to monitor performance (e.g., Boston Harbor, Eagle Harbor, Grasse River). (ORD, U.S. EPA Regions, GLNPO)
- E.4 Using the data provided in recommendation E.1, develop a white paper evaluating the short-term impacts from dredging relative to natural processes and human activities (e.g., resuspension from storm events, boat scour, wave action, and anchor drag). (OERR, U.S. EPA Regions)

*Longer Time Frame*

- E.3 Encourage and promote the development and demonstration of *in-situ* technologies. (ORD, GLNPO)
- E.5 Support the demonstration of cost-effective *ex-situ* treatment technologies and identification of potential beneficial uses of treatment products. (ORD, GLNPO, U.S. EPA Regions)

**F. Baseline, Remediation, and Post-remediation Monitoring***Immediate Time Frame*

- F.1 Develop monitoring guidance fact sheets for baseline, remediation, and post-remediation monitoring, and monitoring during remedy implementation. (ORD, OERR, U.S. EPA Regions, OW)
- F.2 Conduct training and hold workshops for project managers regarding monitoring of contaminated sediment sites. (OERR, ORD, U.S. EPA Regions)

**G. Risk Communication and Community Involvement***Immediate Time Frame*

- G.1 Establish a research program on risk communication and community involvement focusing on developing better methods, models, and tools. (ORD, OERR, U.S. EPA Regions)

**H. Information Management and Exchange Activities***Immediate Time Frame*

- H.1 Establish regional sediment data management systems which can link the regions and program offices with each other and with the National Sediment Inventory. (U.S. EPA Regions, OW, OSWER, GLNPO)
- H.3 Develop national and regional contaminated sediment sites web sites for sharing information. (U.S. EPA Regions, OW, OSWER, GLNPO)
- H.4 Re-establish and expand the Office of Water-sponsored Sediment Network by including more regional representation. (OERR, OW, U.S. EPA Regions)
- H.5 Promote communication and coordination of science and research among Federal agencies. (ORD, OSWER, OW, U.S. EPA Regions, NOAA, U.S. Navy, U.S. ACE, USGS, U.S. FWS)
- H.6 Promote the exchange of scientific information via scientific fora (i.e., workshops, journals, and meetings). (CSMC, OW, OSWER, U.S. EPA Regions, GLNPO)

*Longer Time Frame*

- H.2 Standardize the sediment site data collection/reporting format. Establish minimum protocols for Quality Assurance/Quality Control (QA/QC). (OEI, OW OSWER, U.S. EPA Regions)

Table E-2 is a list of the Acronyms used in the Executive Summary.

**Table E-2. List of Acronyms in Executive Summary.**

APE	Alkylphenol Ethoxylate
CSMC	Contaminated Sediment Management Committee
GLNPO	Great Lakes National Program Office
NOAA	National Oceanic and Atmospheric Administration
OEI	Office of Environmental Information
OERR	Office of Emergency and Remedial Response
OPPTS	Office of Pollution Prevention and Toxic Substances
ORD	Office of Research and Development
OSW	Office of Solid Waste
OSWER	Office of Solid Waste and Emergency Response
OW	Office of Water
PBT	Persistent, Bioaccumulative, and Toxic
QA/QC	Quality Assurance/Quality Control
SF	Superfund Program
SPC	Science Policy Council
TMDL	Total Maximum Daily Load
U.S. ACE	United States Army Corps of Engineers
U.S. EPA	United States Environmental Protection Agency
U.S. FWS	United States Fish and Wildlife Service
USGS	United States Geological Survey

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### **Suggested Uses of This Science Plan**

This Science Plan is designed to satisfy a number of different perspectives and needs. Here are three suggested approaches to its use:

1. For those within or outside the Agency seeking a *general understanding* of the purposes and goals of the Contaminated Sediments Science Plan (what is it and why is it needed?) and some understanding of its history and Agency activities and products, the reader is referred to Chapter One and Two, Goals and Objectives and Current Understanding of Contaminated Sediments, respectively.
  2. Those who understand the contaminated sediments issues in general, but *desire to analyze and assess the validity of the scientific basis* for the science recommendations, should refer to Chapter Three, Assessing the Science on Contaminated Sediments, in conjunction with Section 4.2, Key Recommendations.
  3. *Knowledgeable risk assessors, risk managers, and program managers* who desire to see how the science plan directly impacts their programs will find a quick overview, the key recommendations, and the recommended approach for implementation of the science plan in Chapter Four, Long Range Science Strategy.
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## 1. GOALS AND OBJECTIVES

### 1.1 Introduction

The Contaminated Sediments Science Plan (Science Plan) is a mechanism for U.S. Environmental Protection Agency (U.S. EPA) to develop and coordinate Agency office- and region-wide science activities in the contaminated sediments area. Along with U.S. EPA's contaminated sediment science activities' database (Appendix A), this plan provides an analysis of the current Agency science activities in this area, identifies and evaluates the science gaps, and provides a strategy for filling these gaps.

In 2000, U.S. EPA's Science Policy Council (SPC) initiated the development of the Science Plan because contamination of sediments is a multi-faceted, high profile issue which can benefit from a more comprehensive and higher level of coordination across the Agency. Extensive resources are spent by a number of Agency program offices to address contaminated sediment problems. Program offices addressing this problem include: the Superfund Program (SF), Office of Water (OW), Office of Solid Waste (OSW), Great Lakes National Program Office (GLNPO), Office of Pollution Prevention and Toxic Substances (OPPTS), Office of Research and Development (ORD), and U.S. EPA Regional Offices.

U.S. EPA's mission is to protect human health and to safeguard the natural environment – air, water, and land – upon which life depends. Sediments are an integral component of aquatic ecosystems providing habitats for many aquatic organisms. Many sediment-dwelling organisms at the base of the food chain are eaten by organisms at higher trophic levels. Contaminants in sediments<sup>1</sup> pose a threat to human health, aquatic life, and the environment. Chemicals released to surface waters from industrial and municipal discharges, atmospheric deposition, and polluted runoff from urban and agricultural areas can accumulate to environmentally harmful levels in sediment. Humans, aquatic organisms, and other wildlife are at risk through direct exposure to pollutants or through consumption of contaminated fish and wildlife. Exposure to these contaminants is linked to cancer, birth defects, neurological defects, immune dysfunction, and liver and kidney ailments. Contaminated sediments may also cause economic impacts, at both the local and regional level, on the transportation, fishing, tourism, and development industries.

Sediment contamination is an issue that cuts across offices and jurisdictions throughout the Agency, other Federal agencies (e.g., National Oceanic and Atmospheric Administration (NOAA), U.S. Fish and Wildlife Service (U.S. FWS), U.S. Army Corps of Engineers (U.S. ACE)), state agencies, and tribes. U.S. EPA programs with the authority to address sediment

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Contaminated sediments are defined as soils, sand, and organic matter, or minerals that accumulate on the bottom of a water body and contain toxic or hazardous materials that may adversely affect human health or the environment (U.S. EPA's Contaminated Sediment Management Strategy (U.S. EPA-823-R-98-001)).

contamination operate under the mandate of many statutory provisions including the Comprehensive Emergency Response, Compensation, and Liability Act (CERCLA), the Resource Conservation and Recovery Act (RCRA), the Clean Water Act (CWA), the Oil Pollution Act (OPA), the Toxic Substances Control Act (TSCA), and the Marine Protection, Research, and Sanctuaries Act (MPRSA). Other Federal agencies having authorities that may be used to address contaminated sediments include: U.S. ACE, through the statutory provisions of the Water Resources Development Act (WRDA), Clean Water Act (CWA), and the Marine Protection, Research, and Sanctuaries Act (MPRSA); and U.S. FWS and NOAA, through Natural Resources Damages (NRD) authority.

The Contaminated Sediments Science Plan is the first formal example of an Agency science plan on a specific cross-Agency activity, i.e., contaminated sediment activities shared across U.S. EPA offices and regions. However, it follows in the footsteps of previous U.S. EPA initiatives, such as the *Mercury Action Plan* (U.S. EPA, 2001c), the *Action Plan for Beaches and Recreational Waters (Beach Action Plan)* (U.S. EPA, 1999a), and *A Multimedia Strategy for Priority Persistent, Bioaccumulative, and Toxic (PBT) Pollutants* (U.S. EPA, 1998a). These plans and strategies contain elements of both science plans and management action plans.

## 1.2 Goals of the Contaminated Sediments Science Plan

The Contaminated Sediments Science Plan has three goals which are highlighted in Figure 1-1. The first goal is the development and dissemination of tools and science necessary to address the management of contaminated sediments. The second goal is to enhance the level of coordination and communication of science activities dealing with contaminated sediments across Agency program and regional offices. The third goal is to develop an effective, cost-efficient strategy to promote these scientific activities, including research. These goals promote the vision of providing a strong scientific basis for addressing contaminated sediments. The result will be a more effective science plan with improved environmental decision-making which conserves both human and financial resources.

**Figure 1-1.**

**Contaminated Sediments Science Plan: Goals**

- Development and dissemination of tools and science necessary to address the management of contaminated sediments.
- Enhancement of the level of coordination and communication of science activities across the Agency.
- Development of an effective, cost-efficient strategy to promote these scientific activities and research.

**Contaminated Sediments Science Plan:**

**Expected Results**

- Improved environmental decision-making which is more informed and has a sound science basis.
- More efficient and appropriate expenditure of resources.
- Prevention of duplication of efforts.

The goals of the Science Plan are based upon the strategic guiding principles proposed in the *Strategic Framework for U.S. EPA Science* (U.S. EPA, 2000e) to unify science activities across the Agency. First, this Science Plan uses the Sediment Science Inventory to assemble and evaluate the current contaminated sediment science activities and research across the Agency. Second, it uses effective planning (“doing the right science”) to insure that the most appropriate science activities are being conducted. Third, it uses sound scientific practices and approaches (“doing the science right”), such as Agency and public consultation and external peer review, in its development (Figure 1-2).

### 1.3 Development of the Contaminated Sediments Science Plan

The Contaminated Sediments Science Plan Workgroup has been responsible for the development of this Science Plan, although it has also received wide input from staff from U.S. EPA’s regional and program offices. The development process is described below.

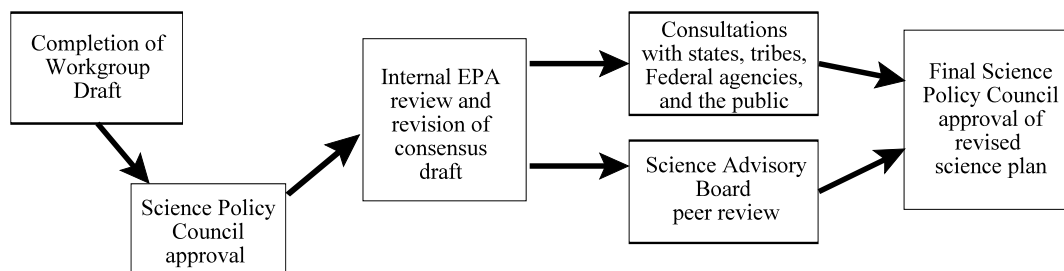
A cross-Agency workgroup of key staff working in the contaminated sediments area, the Contaminated Sediments Science Plan Workgroup, was charged by the SPC with developing a Contaminated Sediments Science Plan (2000). The Workgroup went through the following action steps to develop this Science Plan:

- Collected information on contaminated sediments research and science activities across the Agency.
- Incorporated the identified science activities into U.S. EPA Science Inventory.
- Identified key contaminated sediments issues and data gaps.
- Identified areas for better coordination of contaminated sediments research and science activities.
- Developed a strategy for future contaminated sediments research and science activities.
- Provided for a broad consultative review of the Science Plan both internal and external to the Agency, and a Science Advisory Board (SAB) peer review.
- Developed a strategy to implement the Science Plan and evaluate its performance (see Section 4.3 for details).

Weekly conference calls and a two-day meeting in June 2001 resulted in a draft of the Science Plan which was then circulated for internal review to ensure both accuracy and completeness of the document. External review included other Federal agencies, states, tribes, and others, in addition to a formal peer review by the Agency’s Science Advisory Board. The review process is outlined in Figure 1-2.

Other important inputs to the development of the Science Plan were recommendations contained in the *Contaminated Sediment Management Strategy* (U.S. EPA, 1998b), *A Risk Management Strategy for PCB-Contaminated Sediments* (NRC, 2001a), and *Contaminated Sediments in Ports and Waterways* (NRC, 1997).

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**Figure 1-2. Peer Consultation Process for the Science Plan**

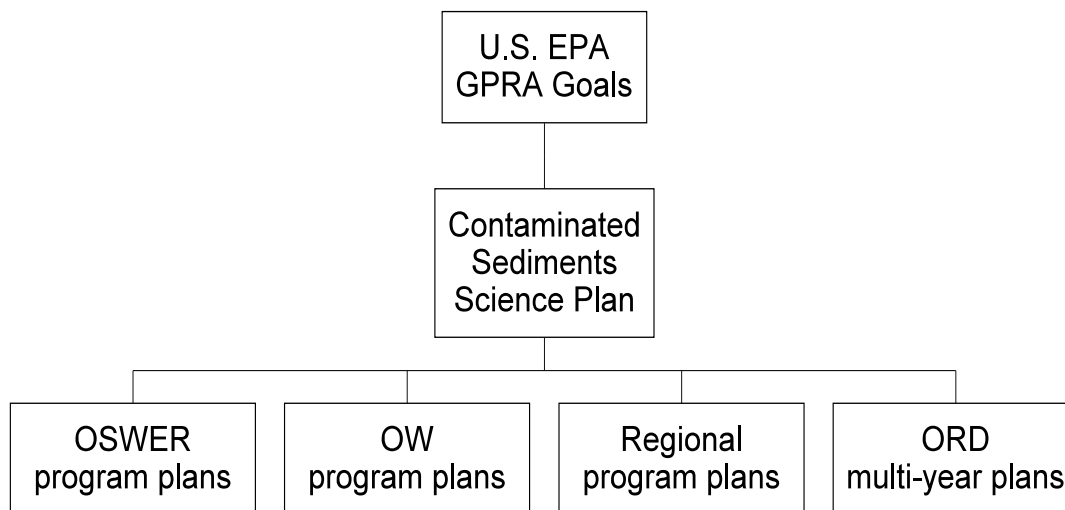
#### 1.4 Linkage of the Science Plan to Agency Planning Processes

Organizations within U.S. EPA use various planning processes to ensure that they meet the Agency's *National Strategic Plan* goals. For planning cross-program work, three tools are available. Two of these tools are management strategies and action plans, which describe commitments by all of the relevant organizations within U.S. EPA to meet specified goals. Examples of these documents are the *Mercury Management Strategy* (U.S. EPA, 2001c) and the *Beaches Action Plan* (U.S. EPA, 1999a). These types of documents usually focus on statutory authorities and implementation by the program offices and regions; research needs are usually considered. The third and newest tool is the science plan. The Contaminated Sediments Science Plan is the first formal example of an agency science plan on a specific cross-Agency activity. A science plan is developed to ensure that science is at the foundation of U.S. EPA activities when multiple offices are addressing complex environmental management issues.

The Science Plan is an important tool that will be used by U.S. EPA regional and program offices in annual budget formulation and work planning processes. Implementation of the Science Plan will help identify the highest priority contaminated sediment needs, coordinate ongoing work across the Agency, avoid duplication of effort, and promote complementary endeavors. Workload requirements to implement Science Plan recommendations need to be evaluated to determine if new budget initiatives will be needed. The Contaminated Sediments Science Plan will receive the same analysis and accountability reviews as any other Agency science/technical assessment priority. Agency annual planning cycles and annual performance measures should be examined by lead offices and regions to see how U.S. EPA is addressing Science Plan recommendations (please refer to Section 4.3 on Science Plan implementation).

The Contaminated Sediments Science Plan encompasses more than research, but where research needs are identified, it will inform the Office of Research and Development (ORD) of the most important contaminated sediment needs to consider during the ORD annual planning

cycle. ORD plans its research through Multi-Year Plans (MYPs) to provide a long-term view of the research direction. Research Coordination Teams (RCTs), comprised of representatives from ORD and U.S. EPA regions and program offices, participate in developing MYPs and determining research priorities. The National Regional Science Council (NRSC), formed in 1997, helps the regions to focus their research needs for ORD's consideration. The multi-year plans and annual resource planning describe how ORD will address recommendations in the Science Plan.



**Figure 1-3: Schematic illustration of the relationship of the Contaminated Sediments Science Plan to U.S. EPA GPRA Goals, program and regional office plans, and ORD's multi-year plans.**

Figure 1-3 is a schematic illustration of the relationship of the Contaminated Sediments Science Plan to U.S. EPA Government Performance and Results Act (GPRA) Goals and program and regional office plans and ORD's multi-year plans. The Science Plan reflects the Agency's integrated efforts to achieve the GPRA goals and objectives, e.g., Goal 5, Objective 1 discussed below in Section 1.5, for contaminated sediments. This effort is accomplished through cooperation among the critical partners, OSWER, OW, ORD and the regional offices, within U.S. EPA.

### 1.5 Continuity of the Science Plan with Agency National Strategic Plan Goals

The relevance of addressing the problem of contaminated sediments to the Agency's mission is reflected in the linkages with U.S. EPA's *National Strategic Plan* goals, as discussed below. The GPRA requires all Federal agencies to develop a five-year strategic plan that establishes clear goals, objectives, and annual performance measures. The strategic plan is updated every three years, and agencies must report back to Congress annually on the results achieved. U.S. EPA's Strategic Plan establishes ten goals that identify the environmental results that U.S. EPA is working to attain. Contaminated sediments is a significant multi-media issue related to the desired results for many of the goals (Table 1-1). Addressing contaminated sediment problems significantly helps the Agency achieve identified environmental outcomes.

**Table 1-1.**

<b>GPRA Goal 2 - Clean and Safe Waters</b>	
OBJECTIVE(S)	POTENTIAL EFFECTS OF CONTAMINATED SEDIMENTS
<ul style="list-style-type: none"> <li>Objective 1 - Reduce consumption of contaminated fish.</li> </ul>	Pollutants can bind to organic particles in the water column, sediments and soils. Contaminants in sediments can enter the aquatic food chain, thus contaminating aquatic organisms and ultimately placing humans at risk of adverse health effects from consumption of these organisms. U.S. EPA is addressing contaminants in sediments in order to prevent contaminant movement through the food chain.
<ul style="list-style-type: none"> <li>Objective 2 - Increase the percentage of waters meeting standards that support healthy aquatic ecosystems.</li> </ul>	Contaminated sediments can cause impairment, threatening healthy aquatic communities.
<b>GPRA Goal 5 - Better Waste Management, Restoration of Contaminated Sites, and Emergency Response</b>	
OBJECTIVE(S)	POTENTIAL EFFECTS OF CONTAMINATED SEDIMENTS
<ul style="list-style-type: none"> <li>Objective 1 - Reduce or control risks to human health and the environment.</li> </ul>	Toxic substances in sediments, such as PCBs and mercury, can enter the aquatic food chain, contaminate fish, and place wildlife and humans at risk through their consumption. U.S. EPA is working to clean up contaminated sediment sites to prevent harm to human health and the environment.
<b>GPRA Goal 6 - Reduction of Global and Cross-Border Environmental Risks</b>	
OBJECTIVE(S)	POTENTIAL EFFECTS OF CONTAMINATED SEDIMENTS
<ul style="list-style-type: none"> <li>Objective 1 - Reduce transboundary threats: North American ecosystems.</li> </ul>	Sediments contaminated with toxics such as mercury represent transboundary threats to ecosystems and human health via water or via global dispersion of air emissions.

<ul style="list-style-type: none"> <li>Sub-objective 1.4 - Restore and maintain the chemical, physical, and biological integrity of the Great Lakes Basin Ecosystem, particularly by reducing the level of toxic substances, protecting human health, and restoring vital habitats.</li> </ul>	Toxic substances such as PCBs and mercury in sediments can enter the aquatic food chain and cause toxic effects. As a result, the presence of toxic substances impacts the chemical, physical, and biological integrity of the Great Lakes and connecting tributaries.
<ul style="list-style-type: none"> <li>Objective 5 - Application of cleaner and cost-effective environmental practices and technologies.</li> </ul>	Development of treatment, recycling, or dredging technologies within the United States and abroad will enhance cost-effective practices which strengthen the economy and protect the environment.
<b>GPRA Goal 8 - Sound Science</b>	
<b>OBJECTIVE(S)</b>	<b>POTENTIAL EFFECTS OF CONTAMINATED SEDIMENTS</b>
<ul style="list-style-type: none"> <li>Objective 2 - Improve models that integrate exposures from multiple pathways.</li> </ul>	Contaminated sediments may cause unwanted, adverse consequences to human life, health, and the environment, and U.S. EPA is committed to using the best available science to reduce the risk.

## 1.6 Document Organization

The Science Plan is organized into four chapters. Chapter One discusses the goals, objectives, and how the Science Plan relates to the Agency's mandate. Chapter Two provides an overview of the contaminated sediment issues across the Agency. The brief description of issues in Chapter Two is intended to provide an introduction to the discussion of contaminated sediment issues, as well as providing the overall context for the more detailed discussion of specific research and science needs given in Chapter Three.

Chapter Three, along with U.S. EPA's contaminated sediment science activities database (Appendix A), is the data collection and analysis section of the Science Plan. It documents the current contaminated sediment science activities ongoing within the Agency, and places these activities within the context of Agency goals. Significant data gaps and uncertainties in methodology/assessment procedures are identified. Finally, it proposes research and science activities to fill those data gaps and resolve related issues.

Chapter Four provides the key recommendations for future Agency science activities, including research, based on the discussion in Chapter Three. For each recommendation, critical U.S. EPA partners and the immediate or long-term nature of the science activity are proposed.

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## 2. CURRENT UNDERSTANDING OF CONTAMINATED SEDIMENTS

### 2.1 Introduction

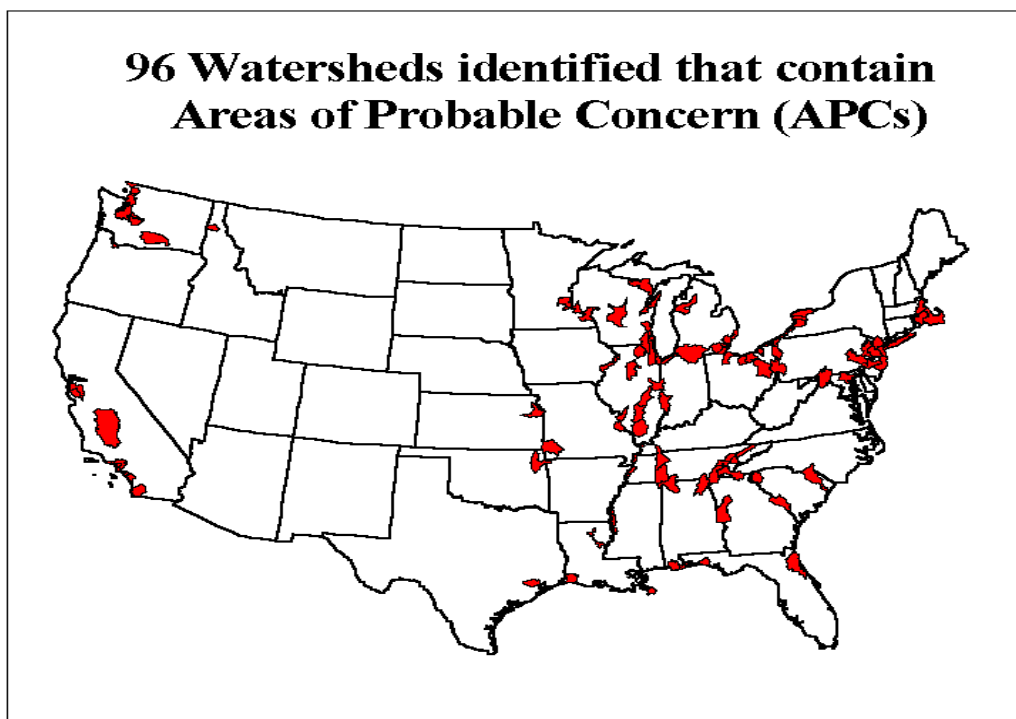
Chapter Two provides an overview of the contaminated sediment problems and issues across U.S. EPA. The brief description of issues in this chapter is meant to provide an introduction to the discussion of contaminated sediment issues, as well as providing the overall context for the more detailed discussion of specific research and science needs given in Chapter Three of this Science Plan.

### 2.2 Scope, Magnitude, and Impacts of Contaminated Sediments

U.S. EPA defines contaminated sediments as soils, sand, and organic matter or minerals that accumulate on the bottom of a water body and contain toxic or hazardous materials that may adversely affect human health or the environment (U.S. EPA, 1998d). In 1997, U.S. EPA published its first National Sediment Quality Survey Report to Congress, *The Incidence and Severity of Sediment Contamination in Surface Waters of the United States* (U.S. EPA, 1997a). This report describes areas where sediment may be contaminated at levels that may adversely affect aquatic life, wildlife, and human health. To evaluate sediment quality nationwide, U.S. EPA developed the National Sediment Inventory (NSI) database, which is a compilation of existing sediment quality data and protocols used to evaluate the data. The NSI was used to produce the first biennial Report to Congress on sediment quality in the United States as required under the Water Resources Development Act of 1992 (U.S. EPA, 1997a). These data were generated from 1980 to 1993, and represent information collected from 1,363 out of 2,111 watersheds in the United States. U.S. EPA's evaluation of the data shows that sediment contamination exists in every region and state of the country and that various waters throughout the United States contain sediment sufficiently contaminated with toxic pollutants to pose potential risks to sediment-dwelling organisms, fish, and humans and wildlife that eat fish. Figure 2-1 shows the locations of ninety-six (96) watersheds identified by U.S. EPA as "areas of probable concern" for potential adverse effects of sediment contamination on human health or the environment. These areas are on the Atlantic, Gulf of Mexico, Great Lakes, and Pacific coasts, as well as in inland waterways, in regions affected by urban and agricultural runoff, municipal and industrial waste discharges, and other pollution sources. U.S. EPA is currently developing the next Report to Congress to be available in 2002.

Sediments act as both a repository and a source of pollutants. Many of these pollutants adsorb onto sediment particles which eventually settle to the bottom of water bodies. Over time these pollutants may be buried under layers of cleaner sediments. But sediments are subject to erosion and resuspension, which may result in the pollutants being released and dispersed

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**Figure 2-1.**

through the water column for transport downstream, uptake through the food chain, or release to the atmosphere via volatilization, for transport through the air and re-deposition into lakes and other waterways.

The bioaccumulative, persistent, and toxic contaminants in sediment affect aquatic life and wildlife through direct contact, ingestion, and food chain effects. These impacts include reproductive effects, developmental effects, birth defects, cancer, tumors, and other deformities. Humans are also at risk through direct exposure to pollutants or through consumption of contaminated fish and wildlife. Exposure to these contaminants is linked to cancer, birth defects, neurological defects (e.g., in infants and children), immune dysfunction, and liver and kidney ailments. Research is currently underway studying the potential for endocrine disruption effects due to contaminants in sediments.

In addition, contaminated sediments can impose costs on society through lost recreational opportunities and revenues. For example, fish consumption advisories can have a significant impact on the use of our natural resources. Approximately twenty-three percent of the nation's lake acreage and nine-point-three percent (9.3%) of the nation's river miles are under advisory

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for fish consumption. Many of these advisories can be linked to contaminated sediments. Contaminated sediments may also cause severe economic impacts at both the local and regional level. Economic risk may be felt by the transportation, fishing, tourism, and development industries. In one Great Lakes harbor, the Indiana Harbor Ship Canal, contaminated sediments are imposing an annual cost of eleven to seventeen million dollars (Peck et al., 1994).

### **2.3 Overview of Major Sediment Issues and Needs Across the Agency**

The management of contaminated sediments is a multi-faceted challenge for the Agency. As a multi-media issue, aspects of contaminated sediment management fall under different parts of U.S. EPA. This section provides an overview of the major contaminated sediment issues from across the Agency. This discussion is meant to provide the overall context for the discussion of the specific research and science needs that follow in Chapter Three.

#### *Water Quality Standards*

The Clean Water Act (CWA) was established to restore and maintain the quality of waters in the United States (U.S.). Sediment underlying surface water is recognized as a significant source of, and sink for, toxic pollutants in the aquatic environment. Therefore, addressing sediment quality is an integral component of water quality standards programs. It is necessary to incorporate appropriate sediment quality protection policies and procedures to protect and maintain designated water uses. At a minimum, states and authorized tribes must provide water quality for the protection and propagation of fish, shellfish, and wildlife, and provide for recreation in and on the water, where attainable (CWA Section 101(a)). Sediment quality can affect the attainment of designated uses. It is therefore both necessary and appropriate to assess and protect sediment quality as an essential component of the total aquatic environment in order to achieve and maintain designated uses.

#### *Development of Total Maximum Daily Loads (TMDLs)*

Section 303(d) of the CWA and its implementing regulations (40 CFR 130.7) require states and authorized tribes to establish Total Maximum Daily Loads (TMDLs) of pollutant discharge at levels necessary to achieve applicable water quality standards. TMDLs identify the loading capacity of the water body, wasteload allocations for point sources, and load allocations (LA) for nonpoint sources and natural background. About 40,000 TMDLs are required for about 20,000 impaired water bodies in U.S., based on U.S. EPA's 1998 list of impaired waters. About twenty-four percent of the TMDLs (based on 1998 data from the TMDL tracking system) are for pollutants that are also found in contaminated sediments. These TMDLs will require some analysis for the contribution of pollutants from contaminated sediments.

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Developing a TMDL is a mass balance exercise that considers contaminant loads (particulate and dissolved) from all sources, incorporates dilution and downstream fate and transport, includes a margin of safety, and allocates the permissible pollutant load among point sources, nonpoint sources, and natural/background sources. A TMDL is a written analysis and plan established to ensure that a water body or group of water bodies within a watershed will attain and maintain water quality standards throughout the year. A TMDL identifies the wasteload allocations and load allocations that together, along with a consideration of a margin of safety and seasonal variations, will achieve water quality standards.

### *Fish Advisories*

The states, U.S. territories, and Native American tribes have primary responsibility for protecting their residents from the health risks of consuming contaminated, non-commercially caught fish and wildlife. They do this by issuing consumption advisories for chemicals such as mercury or PCBs for the general population as well as for sensitive subpopulations (e.g., pregnant women, nursing mothers, and children). These advisories inform the public when high concentrations of chemical contaminants have been found in local fish and wildlife and include recommendations to limit or avoid consumption of certain fish and wildlife species from specific water bodies or water body types. Approximately twenty-three percent of the nation's lake acreage and over nine percent (9.3%) of the nation's river miles are under advisory for fish consumption. Many of these advisories can be linked to contaminated sediments. One hundred percent of the Great Lakes and their connecting waters and seventy-one percent of coastal waters of the contiguous forty-eight states were under advisories in 2000. It is expected that addressing sediment quality issues will reduce the need for issuance of such consumption advisories.

### *Management of Dredged Material from Navigational Dredging*

Several hundred million cubic yards of sediment are dredged from United States ports, harbors, and waterways each year to maintain and improve the nation's navigation system for commercial, national defense, and recreational purposes. Of the total sediment volume dredged, approximately one-fifth is disposed of in the ocean (i.e., waters outside the baseline) at designated sites in accordance with Section 103 of the Marine Protection, Research, and Sanctuaries Act (MPRSA). Most of the remaining dredged material is discharged into inland waters of the United States (i.e., waters inside the baseline), placed in confined disposal facilities with a return flow to waters of the U.S. (i.e., inland waters and waters out to three miles from the baseline), or used for beneficial purposes (including as fill) in waters of the U.S., all of which are regulated under Section 404 of the CWA.

U.S. Army Corps of Engineers (U.S. ACE), the Federal agency designated to maintain navigable waters, conducts a majority of this dredging and disposal under its Congressionally authorized civil works program. The balance of the dredging and disposal is conducted by a number of local public and private entities. In either case, the disposal is subject to a regulatory

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program administered by U.S. ACE and U.S. EPA under the above statutes. U.S. EPA shares the responsibility of managing dredged material, principally in the development of the environmental criteria by which proposed discharges are evaluated and disposal sites are selected, and in the exercise of its environmental oversight authority. Estimates by U.S. ACE indicate that only a small percentage of the total annual volume of dredged material disposed (approximately three million to twelve million cubic yards) is contaminated such that special handling and/or treatment is required.

### *Superfund Sites*

Superfund is the Federal government's program to clean up the nation's uncontrolled hazardous waste sites. The National Priorities List (NPL) is a published list of priority hazardous waste sites in the country that are being addressed by the Superfund program. The regions have identified about four hundred NPL sites potentially having contaminated sediments. These include a number of very large contaminated sediment sites where remedies may cost up to several hundreds of millions of dollars. The major issues associated with contaminated sediments include risks to human health and the environment, limited disposal space, high costs, and the uncertainties related to risk management options.

### *Resource Conservation and Recovery Act (RCRA) Sites*

Like the Superfund program, Resource Conservation and Recovery Act (RCRA) sites/facilities are remediated to support current and reasonably anticipated uses. RCRA authority for Corrective Action is to clean up releases from a specific facility; therefore it is less amenable to an area-wide approach than Superfund. The number of RCRA sites with contaminated sediment issues is smaller than the number of Comprehensive Emergency Response, Compensation, and Liability Act (CERCLA) contaminated sediment sites. In March 1999, the regions and states identified seventeen RCRA Corrective Action sites with sediment contamination problems. The major issues associated with contaminated sediments related to RCRA sites include uncertainties regarding risks to human health and the environment and uncertainties related to risk management options.

### *Deposition of Contaminants via Long-Range Air Transport*

Over the past thirty years, scientists have collected a large amount of data indicating that air pollutants can be redeposited on land and water, sometimes at great distances from their original sources. These data demonstrate that air transport of contaminants can be an important contributor to declining water quality. These air pollutants can have undesirable health and environmental impacts: contributing to fish body burdens of toxic chemicals, causing harmful algal blooms through deposition of nutrients, and impacting water quality, resulting in unsafe drinking water.

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In response to mounting evidence indicating that air pollution contributes significantly to water pollution, Congress added the Great Waters Program (Section 112(m)) when it amended the Clean Air Act in 1990. The Great Waters Program, a joint program including U.S. EPA and NOAA, is designed to study and address the effects of air pollution on the water quality and ecosystems of the Great Lakes, Lake Champlain, the Chesapeake Bay, and estuaries that are part of the National Estuary Program or the National Estuarine Research Reserve System.

*Persistent, Bioaccumulative, and Toxic Pollutants (PBTs)*

PBTs often accumulate in sediments. The Agency has three major efforts related to PBTs: a PBT Initiative, the Binational Strategy to Reduce Toxics, and Testing Requirements under the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) and the Toxic Substances Control Act (TSCA) for Pesticides and Toxic Substances use.

PBT Initiative

U.S. EPA has developed and is implementing a national multi-media strategy for the reduction of persistent, bioaccumulative, toxic chemicals (PBTs), entitled the PBT Initiative. The goal of this strategy is to reduce risks to human health and the environment from existing and future exposure to priority pollutants. The four main elements of the PBT Initiative are:

1. Develop and implement national action plans to reduce priority PBT pollutants, utilizing the full range of U.S. EPA tools.
2. Continue to screen and select more priority pollutants for action.
3. Prevent new PBTs from entering the marketplace.
4. Measure progress of these actions against U.S. EPA's Government Performance Results Act (GPRA) goals and national commitments.

U.S. EPA's challenge in reducing risks from PBTs stems from the pollutants' ability to travel long distances, to transfer rather easily among air, water, and land, and to linger for generations in people and the environment. Although much work has been done over the years to reduce the risk associated with these chemicals, they frequently occur at levels of concern in fish tissue. All of the substances that are causing the fish consumption advisories are PBTs.

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Great Lakes Binational Toxics Strategy

The Great Lakes Binational Toxics Strategy provides a framework for actions to reduce or eliminate persistent, toxic substances from the Great Lakes Basin, especially those that bioaccumulate. The Strategy was developed jointly by Canada and the United States in 1996 and 1997 and was signed April 7, 1997. The Strategy establishes reduction challenges for an initial list of persistent, toxic substances targeted for virtual elimination ('Level One' substances) which are synonymous with the first twelve priority pollutants identified through the PBT Initiative. These substances have been associated with widespread long-term adverse effects on wildlife in the Great Lakes, and, through their bioaccumulation, are of concern for human health. The Strategy provides a framework for action to achieve specific quantifiable reduction "challenges" in the 1997 to 2006 time frame for specific toxic substances.

Testing Pesticides and Toxic Substances for Registration and Use

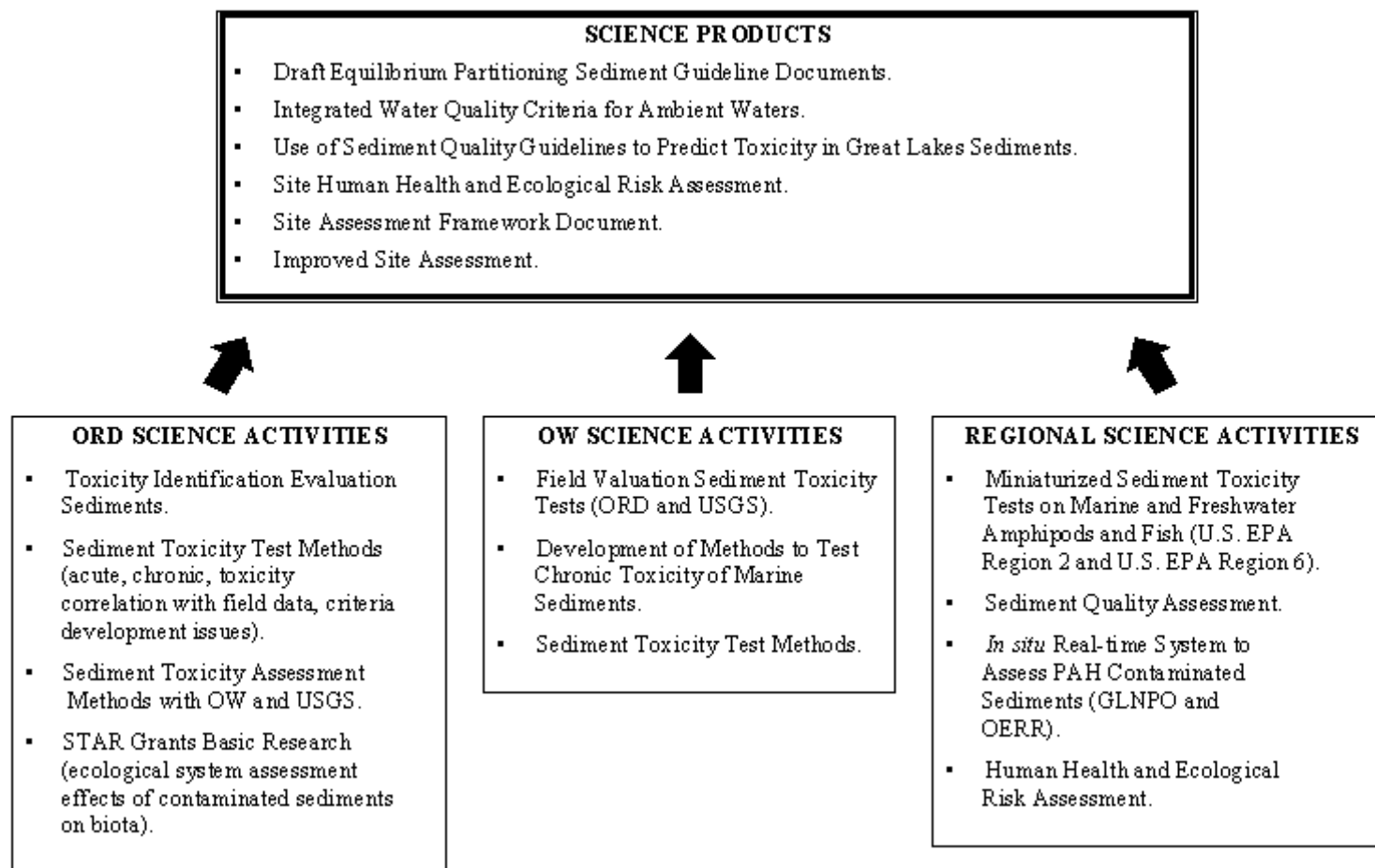
The Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) and the Toxic Substances Control Act (TSCA) provide U.S. EPA the authority to ban or restrict the use of pesticides and toxic chemicals that have the potential to contaminate sediment. These actions can be taken if environmental or human health risks are determined to be unacceptable. Sediment toxicity testing can be required to assess the risks of sediment contamination posed by pesticides and other chemicals. These tests must be applied under the authority of FIFRA and TSCA in a strategy to systematically evaluate the risks of sediment contamination.

**2.4 Recent U.S. EPA Contaminated Sediment Science Activities and Products**

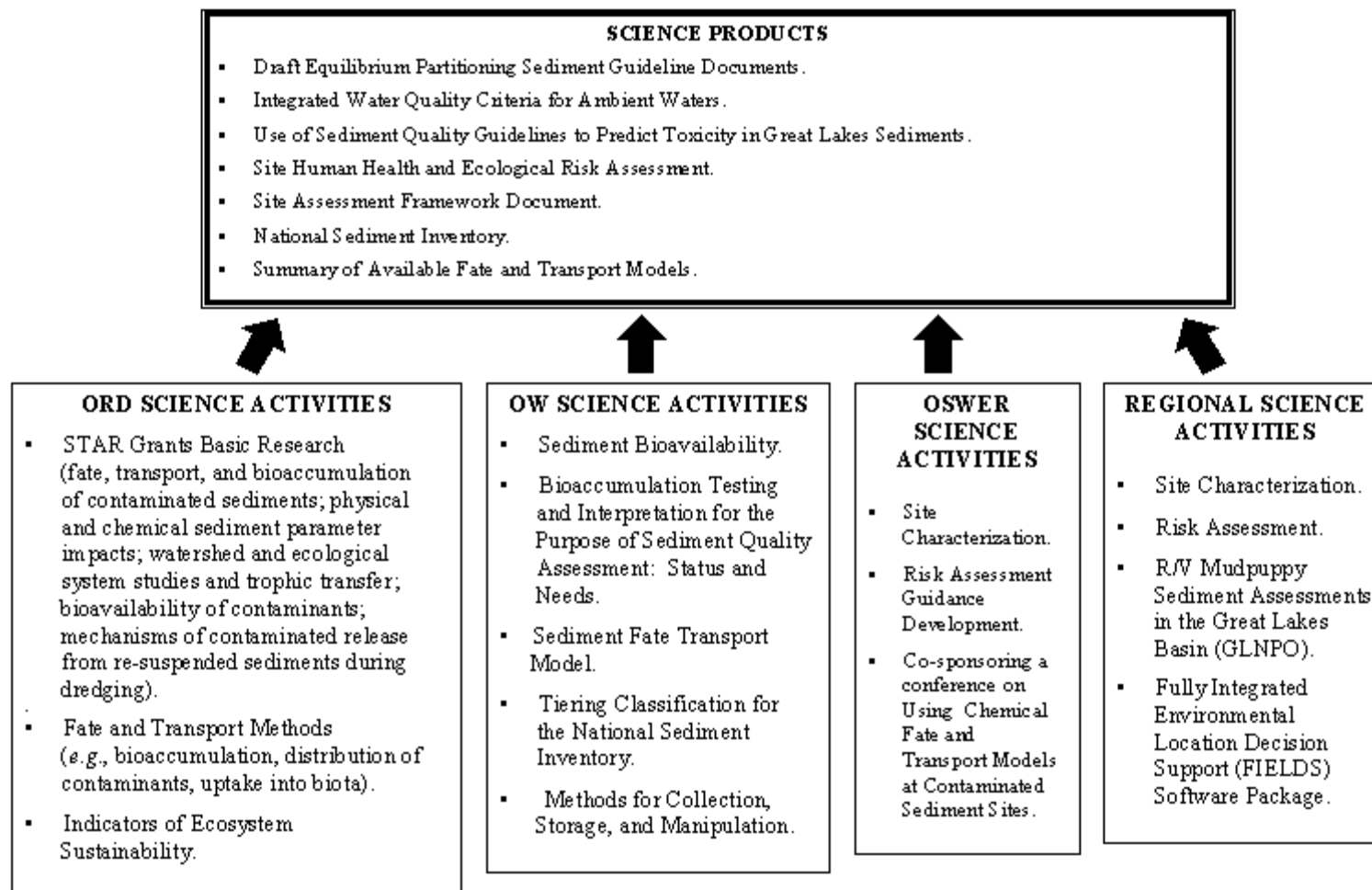
To address the contaminated sediment issues discussed above, U.S. EPA produces scientific products such as guidance documents and risk assessments. Various scientific activities, internal and external to U.S. EPA, support the development of these scientific products. Figures 2-2 through 2-4 summarize the major recent science products and activities in contaminated sediments by OW, OERR, ORD, and U.S. EPA Regions. The information has been separated into effects and assessment, sediment characterization and fate and transport, and remediation monitoring and managing contaminated sediments. Cross-Agency relationships have resulted in focused scientific activities to more directly support science products and program office or regional decisions. A detailed listing of U.S. EPA's contaminated sediment science activities database, including program and regional office activities, is contained in Appendix A. It presents recent projects that include scientific areas on program implementation, human health and ecological effects and assessment, exposure and modeling, and remediation and risk management. Collaboration among U.S. EPA scientists and engineers enhances the use of quality scientific information in risk management decision-making.

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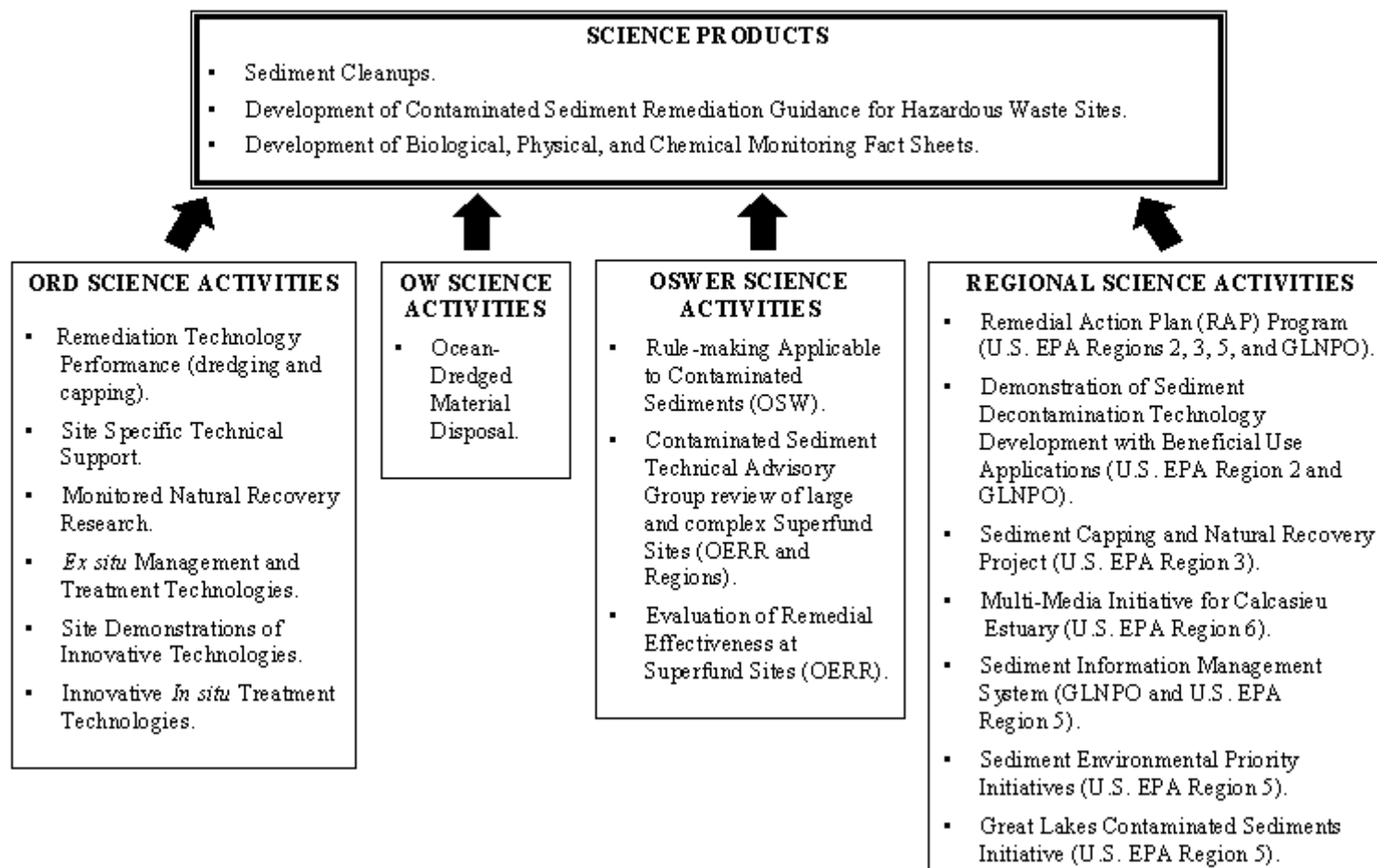
**Figure 2-2. CURRENT AGENCY SCIENCE ACTIVITIES AND PRODUCTS REGARDING CONTAMINATED SEDIMENT EFFECTS AND RISK ASSESSMENT**



**Figure 2-3. CURRENT AGENCY SCIENCE ACTIVITIES AND PRODUCTS REGARDING CONTAMINATED SEDIMENT CHARACTERIZATION AND ENVIRONMENTAL FATE AND TRANSPORT**



**Figure 2-4. CURRENT AGENCY SCIENCE ACTIVITIES AND PRODUCTS REGARDING REMEDIATION, MONITORING, AND MANAGING CONTAMINATED SEDIMENTS**



## 2.5 Overview of Communication and Collaboration Activities

Management of contaminated sediments requires a coordinated effort which surpasses any single legislative authority or media. Comprehensive, multi-media responses that combine multiple programs, agencies, and resources with public and private support can result in resolution of the contaminated sediments problem. This section will provide an overview of how such coordinated multi-media efforts occur within and outside of U.S. EPA.

### 2.5.1 Collaborative Efforts Within U.S. EPA

Several key collaborative efforts within the Agency are relevant to the Science Plan and include the Contaminated Sediment Management Committee (CSMC), publication of the *Contaminated Sediment Management Strategy* (CSMS) (U.S. EPA, 1998d), development of the National Sediment Inventory, the Agency-wide Science Inventory, and cross-media teams such as U.S. EPA Region 5 Sediment Team that focus their efforts on the contaminated sediments issue. These are briefly discussed below. In addition, there has been enhanced Headquarters collaboration with the regions and coordination across media programs in the regions.

- U.S. EPA published the Contaminated Sediment Management Strategy (CSMS) in April 1998. The CSMS summarizes U.S. EPA's understanding of the extent and severity of sediment contamination; describes the cross-program policy framework in which U.S. EPA intends to promote consideration and reduction of ecological and human health risks posed by sediment contamination; and identifies actions U.S. EPA believes are needed to bring about consideration and reduction of risks posed by contaminated sediments (see Figure 2-5 for goals).
  - The Contaminated Sediment Management Committee (CSMC) was established to coordinate all the appropriate programs and their associated regulatory authorities involved in the management of contaminated sediments. CSMC includes representation at the Office Director and Regional Division Director level from OSWER, OW, ORD, OECA, and many of the regions. To deal with the management of contaminated sediments across Agency programs and regions, a plan has been developed outlining the next steps for the Agency in the management of contaminated sediments, and describing the commitments from U.S. EPA program offices to develop and apply sound science in managing contaminated sediments. The plan shows how U.S. EPA is coordinating activities and utilizing multiple authorities to achieve overall environmental goals. The CSMC will have an overarching role in ensuring the implementation of this plan.
  - The National Sediment Inventory is a national database and repository of data regarding sediment quality in the United States. In accordance with the requirements of Title V of the Water Resources Development Act, U.S. EPA's Office of Water (OW) developed the
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first comprehensive national survey of data regarding sediment quality and compiled all available information in a national database. The database includes information regarding quantity, chemical and physical composition, and geographic location of pollutants in sediments. This information was summarized in a report to Congress entitled, *The Incidence and Severity of Sediment Contamination in Surface Waters of the United States* (U.S. EPA, 1997a). The National Sediment Inventory is being updated on a regular basis and will be used to assess trends in sediment quality.

- U.S. EPA's Science Inventory is a database under development of Agency research and science activities for a number of different topics, one of which is contaminated sediments. The Office of Science Policy is coordinating development of the Science Inventory for the Agency. The portion on contaminated sediments identifies the current scientific activities and research efforts in the contaminated sediments area from across the Agency.
- Contaminated sediments were designated as an U.S. EPA Region 5 Environmental Priority in 1995 due to both the extent and severity of the problem across the region. Because a coordinated, multi-media effort would be required to address the problem, a Regional Team was formed with members representing regional programs and the Great Lakes National Program Office. The Team helped develop a strategy to implement a coordinated approach to program and office efforts to address contaminated sediments sites and provide technical expertise to the region, state agencies, and others.

**Figure 2-5. The Goals of the Contaminated Sediment Management Strategy (CSMS)**

- Prevent the volume of contaminated sediment from increasing.
- Reduce the volume of existing contaminated sediment.
- Ensure that sediment dredging and dredged material disposal are managed in an environmentally sound manner.
- Develop scientifically sound sediment management tools for use in pollution prevention, source control, remediation, and dredged material management.

## **2.5.2 External Collaborative Efforts**

The Agency recognizes the importance of an open dialogue and active collaboration with Federal and state agencies and other stakeholders who are concerned with the contaminated sediment issue. U.S. EPA is participating in, is sponsoring, or has sponsored a number of multi-stakeholder collaborations concerned with the various aspects of this issue. These efforts have

been diverse. For example, the National and Regional Dredging Teams, co-chaired by U.S. EPA and U.S. ACE, were formed in response to the final report of the Interagency Working Group on the Dredging Process in order to provide a mechanism for timely resolution of conflicts over navigational dredging by involving all agencies and maximizing interagency coordination.

U.S. EPA is working with the National Environmental Policy Institute (NEPI) through participation on the National Sediment Dialogue to develop a white paper with insights and expertise on all aspects of risk management of contaminated sediments. OSWER's Technology Innovation Office (TIO) and ORD's NRMRL are co-sponsors of the Remedial Technologies Development Forum (RTDF) Sediment Action Team, a public- and private-sector partnership created to undertake the research, development, demonstration, and evaluation efforts needed to achieve common cleanup goals (See Figure 2-6). It is anticipated that these collaborations will continue and expand through the implementation of the Science Plan.

**Figure 2-6. Examples of External Collaborative Efforts**

- Contaminated Aquatic Sediment Remedial Guidance Workgroup: developing Superfund Contaminated Sediments Remediation Guidance; involves ORD, OW, and the regions, as well as inter-agency participation from NOAA, USGS, U.S. FWS, and U.S. ACE.
- National Dredging Team (NDT): includes members from U.S. EPA, U.S. ACE, NOAA (OCRM and NMFS), USCG, USGS, and MARAD.
- RaDiUS database of Federally-funded research.
- Great Lakes Dredging Team: Comprised of Great Lakes states, Great Lakes Commission and six Federal agencies, including U.S. EPA.
- Inter-state Technology and Regulatory Cooperation (ITRC) Sediment Remediation Team.
- U.S. EPA Region 5 U.S. EPA/State Superfund Conference Calls.
- NEPI National Sediments Dialogue.
- Ashtabula River Partnership.
- Remedial Technologies Development Forum (RTDF).

In addition to these direct collaborative efforts with other agencies, the RAND Corporation, in cooperation with the National Science Foundation (NSF), was funded by the Federal government to develop a database called RaDiUS (Research and Development in the United States). This database tracks government resources and research and development activities. RaDiUS helps the research community understand the research being conducted by the Federal government in order to eliminate duplication of effort and promote collaboration. The database was searched using the term "sediment" and identified more than 650 projects in eight agencies: U.S. Department of Agriculture (USDA), Department of Commerce (DOC), Department of Defense (DoD), Department of Energy (DOE), Department of Interior (DOI), U.S. EPA, National Aeronautics and Space Administration (NASA), and National Science Foundation

(NSF). The results of this search were considered in the development of this plan and will be revisited as the plan develops and is implemented.

## 2.6 National Research Council (NRC) Report on PCB-Contaminated Sediments

In an effort to address the controversial issues related to the management of PCB-contaminated sediments, the U.S. Congress directed U.S. EPA to “enter into an arrangement with the National Academy of Sciences (NAS) to conduct a review which evaluates the availability, effectiveness, costs, and effects of technologies for the remediation of sediments contaminated with polychlorinated biphenyls, including dredging and disposal.” In response to this Congressional request, the National Research Council (NRC) published *A Risk-Management Strategy for PCB-Contaminated Sediments*, which was released in March, 2001 (NRC, 2001a). Among the eleven major conclusions and recommendations made by the committee, one was directed at the research areas shown in Figure 2-7.

**Figure 2-7. Recommendations for Further Research on PCB-Contaminated Sediments (NRC, 2001a)**

- A better assessment of human health and ecological risks associated with mixtures of individual chlorobiphenyls present in specific environmental compartments.
- The impact of co-contaminants on PCB risk assessments and risk management strategies.
- Processes governing the fate of PCBs in sediments, including erosion, suspension, transport of fine cohesive sediments, pore water diffusion, biodegradation, and bioavailability.
- Improvement of *ex situ* and *in situ* technologies associated with removal or containment of PCB-contaminated sediments, treatment of PCB-contaminated material, and disposal of such sediments.
- Pilot scale testing of innovative technologies, such as biodegradation and *in situ* active treatment caps, to assess their effectiveness and applicability to various sites.
- The impact of continuing PCBs releases and global environmental cycling on site-specific risk assessments.

## 2.7 National Research Council Report on Contaminated Marine Sediments

The National Research Council established the Committee on Contaminated Marine Sediments to “assess the nation’s ability for remediating contaminated sediments and to chart a course for the development of management strategies.” The Committee published the results of their findings in *Contaminated Sediments in Ports and Waterways* (NRC, 1997). In general, the report concluded that there is no need to delay sediment remediation projects in anticipation of a ground-breaking remediation technology, since no such technology is on the horizon. The

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recommendations are organized into three areas: decision-making, remediation technologies, and project implementation. A summary of the recommendations is given in Figure 2-8.

**Figure 2-8. National Research Council Recommendations on Contaminated Marine Sediments (NRC, 1997)**

DECISION-MAKING

- U.S. EPA and U.S. ACE should continue to develop uniform/parallel procedures for environmental/human health risks associated with freshwater, marine, and land-based disposal, containment, or beneficial reuse of contaminated sediments.
- Because consensus building is essential for project success, Federal, state, and local agencies should work together with appropriate private-sector stakeholders to interpret statutes, policies, and regulations in a constructive manner so that negotiations can move forward and sound solutions are not blocked or obstructed.
- To facilitate the application of decision-making tools, U.S. EPA and U.S. ACE should: (1) develop and disseminate information to stakeholders concerning the available tools; (2) use appropriate risk analysis techniques throughout the management process, including the selection and evaluation of remediation strategies; and (3) demonstrate the appropriate use of decision analysis in an actual contaminated sediments case.
- U.S. ACE should modify the cost-benefit analysis guidelines and practices it uses to ensure the comprehensive, uniform treatment of issues involved in the management of contaminated sediments.
- U.S. ACE should revise its policies to allow for the implementation of placement strategies that involve the beneficial use of contaminated sediments even if they are not lowest cost alternatives. In addition, regulatory agencies involved in contaminated sediments disposal should develop incentives for and encourage implementation of beneficial use alternatives.
- Federal and state regulators, as well as ports, should investigate the use of appropriate legal and enforcement tools to require upstream contributors to sediment contamination to bear a fair share of cleanup costs.

TECHNOLOGIES

- U.S. EPA and U.S. ACE should develop a program to support research and development and to demonstrate innovative technologies specifically focused on the placement, treatment, and dredging of contaminated marine sediments. Innovative technologies should be demonstrated side-by-side with the current state-of-the-art technologies to ensure direct comparisons. The results of this program should be published in peer-reviewed publications so the effectiveness, feasibility, practicality, and cost of various technologies can be evaluated independently. The program should span the full range of research and development, from the concept stage to field implementation.
- U.S. ACE and U.S. EPA should develop guidelines for calculating the costs of remediation systems, including technologies and management methods, and should maintain data on the costs of systems that have actually been used. The objective should be to collect and maintain data for making fair comparisons of remediation technologies and management methods based on relative costs, as well as their effectiveness in reducing risks to human health and ecosystems.
- U.S. EPA and U.S. ACE should support research and development to reduce contaminant losses from confined disposal facilities and confined aquatic disposal, to promote the reuse of existing confined disposal facilities, and to improve tools for the design of confined disposal facilities and confined aquatic disposal systems and for the evaluation of long-term stability and effectiveness.

**NRC Recommendations on Contaminated Marine Sediments (NRC, 1997) (continued)**

- U.S. EPA and U.S. ACE should sponsor research to develop quantitative relationships between the availability of contaminants and the corresponding risks to humans and ecosystems. The overall goal should be to enable project evaluation using performance-based standards, specifically the risk reduction from in-place sediments; disturbed sediments; capped sediments; confined disposal facilities and confined aquatic disposal; and sediments released following physical, chemical, thermal, and biological treatments.
- U.S. EPA and U.S. ACE should support the development of monitoring tools to assess the long-term performance of technologies that involve leaving contaminants in or near aquatic environments. Monitoring programs should be demonstrated with the goal of ensuring that risks have been reduced through contaminant isolation.
- Funding should continue for research and development of innovative beneficial uses for contaminated sediments and the development of technical guidelines and procedures for environmentally acceptable, beneficial reuse

**PROJECT IMPLEMENTATION**

- U.S. EPA and U.S. ACE should conduct joint research and development projects to advance the state of the art in site assessment technologies. Objectives should include the identification and development of advanced survey approaches and new and improved chemical sensors for both surveying and monitoring.
- U.S. ACE should support demonstrations of innovative site assessment technologies. Remote sensing technologies should be demonstrated in an integrated survey operation at a major contaminated sediment site. The project should demonstrate the capability of accurately defining a hot spot or larger critical area that requires either *in situ* treatment or accurate removal for *ex situ* treatment or placement.

**2.8 Long-term Trends Affecting Contaminated Sediments**

The purpose of this Science Plan is to capture not only immediate and intermediate scientific needs for contaminated sediment management, but also longer term trends or impacts which may be “outside the box of regulatory focus,” yet are of critical environmental concern. In many cases, these scientific concerns encompass more than the area of contaminated sediments. A listing of some of these concerns is given in Figure 2-9.

The sources and activities that lead to sediment contamination are likely to increase with the growth in world population and economic development. Atmospheric loadings are likely to increase as well. Under most current projections of future conditions here and abroad, societal and governmental pressure will increase to maintain navigation channels, protect food and water supplies, and develop housing, business, and recreation along

**Figure 2-9. Environmental Trends Relevant to Contaminated Sediments**

- More development around waterfront.
- Long-range transport of contaminants.
- TMDL challenge.
- Nonpoint source controls.
- Extensive sites with multiple communities.
- Large/complex sites (“mega” sites).
- Limited disposal capacity.
- High costs of remediation vs. shrinking resources.

waterways and coastlines. While it is extremely important to develop the capability to detect and manage contaminated sediments, that strategy alone is unlikely to achieve the desired levels of environmental protection. Extensive scientific information should also be obtained and analyzed to understand environmental loadings, develop measures and management strategies to prevent additional loadings to sediments and develop alternative uses, promote recycling, and minimize the generation of waste to reduce future loadings. Such approaches (e.g., conceptual models of the sources and pathways that lead to contaminated sediments and global budgets of metals and persistent and bioaccumulative organics) should be integrated with other U.S. EPA programs, Federal agencies and states, industrial trade groups, stakeholders, and foreign countries. Consideration of these broader scientific/societal issues in this kind of strategy will require national and international collaboration.

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### 3. ASSESSING THE SCIENCE ON CONTAMINATED SEDIMENTS

#### 3.1 Introduction

This chapter discusses current contaminated sediment science activities within the Agency and identifies science needs within eight major topic areas. The major topics are: sediment site characterization; exposure assessment; health effects and risk assessment; ecological effects and risk assessment; sediment remediation; baseline, remediation, and post-remediation monitoring; risk communication and community involvement; and information management and exchange activities. Key scientific questions were developed for each major topic in order to focus discussions on scientific needs and to identify recommended science activities to address these questions. Future updates to the Contaminated Sediments Science Plan will re-evaluate the current state of the science and identify any new and emerging science issues and needs.

#### *Key Scientific Questions:*

**Sediment Site Characterization:** What physical, chemical and biological methods best characterize sediments and assess sediment quality?

**Exposure Assessment:** What are the primary exposure pathways to humans and wildlife from contaminants in sediments and how can we reduce uncertainty in quantifying and modeling the degree of exposure?

**Health Effects and Risk Assessment:** What are the risks associated with exposure to contaminants in sediments through direct and indirect pathways?

**Ecological Effects and Risk Assessment:** What are the risks associated with exposure to contaminants in sediments to wildlife species and aquatic communities?

**Sediment Remediation:** What sediment remedial technology or combination of technologies is available to effectively remediate sites?

**Baseline, Remediation, and Post-remediation Monitoring:** What types of monitoring are needed to ensure that the implemented remedy meets remedial performance goals and does not cause unacceptable short-term effects?

**Risk Communication and Community Involvement:** How can we provide communities with more meaningful involvement in the contaminated sediments cleanup process?

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**Information Management and Exchange Activities:** How do we improve information management and exchange activities on contaminated sediments across the Agency?

U.S. EPA science activities on contaminated sediments are primarily contained in OSWER, OW, ORD, GLNPO, and the regions. The contaminated sediment science activities database contained in Appendix A presents recent projects on various scientific topics of concern in the assessment and management of contaminated sediments. Areas addressed in the table are divided into major science areas. Program implementation projects include remediation, monitoring, pilot studies, and initiatives. Human health and ecological effects and assessment projects include productive cross-Agency efforts on equilibrium partitioning of contaminants, ecotoxicological method development, risk assessments, and characterization studies. Exposure and modeling tasks are also presented and they address tasks such as Total Maximum Daily Loads (TMDLs), bioavailability, and modeling. Remediation and risk management projects include guidance development, technology development and evaluation, site specific efforts, field demonstration of technologies, and information management systems.

### 3.2 Sediment Site Characterization

U.S. EPA has evaluated sediment quality data collected from more than 21,000 sampling stations nationwide (U.S. EPA, 1997a). This evaluation has indicated that contaminated sediment sites occur in different types of water bodies in every state. The water bodies affected include streams, lakes, harbors, near shore areas, and oceans. U.S. EPA has recognized that in different water body types, many factors can affect the kinds and magnitude of impacts that contaminated sediments have on the environment (U.S. EPA, 1992b). These factors include hydrology, physical and chemical characteristics of the sediment, types of contaminants present and their associated human health or ecological effects, and synergistic or antagonistic effects of contaminants. Sediment characterization and assessment tools vary in their suitability and sensitivity for detecting different endpoints and effects. For example, the most appropriate method for conducting screening level assessments may not provide adequate information for definitive risk assessments. Similarly, methods providing information about food chain exposure may not answer questions about direct toxicity. It is, therefore, necessary to match the assessment method used with the site or program-specific objectives of a study being conducted. For this reason, multiple complementary characterization or assessment methods are used to assess sediment quality. Assessments of sediment quality have commonly involved: use of various spatial and temporal sampling strategies, analyses of physical parameters, analyses of chemical parameters, biological testing (both laboratory and *in situ* testing for toxicity and bioaccumulation of contaminants), and evaluation of ecological indicators such as benthic community structure.

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### 3.2.1 Sampling Strategies (temporal and spatial)

Selection of an appropriate sampling design is one of the most critical steps in assessment and characterization studies. The sampling design chosen will depend upon the study objectives. U.S. EPA (2001b) describes the factors to consider in designing a sampling study. The study design should control extraneous sources of variability and error so that data are representative for the objectives being addressed. Sampling designs for spatially distributed variables fall into two major categories: 1) random or probabilistic, and 2) targeted designs. Probability-based designs avoid bias in the results of sampling by randomly assigning and selecting sampling locations. In targeted, judgmental, or model-based designs, sampling locations are selected on the basis of prior knowledge or variables such as estimated loading, depth, salinity, and substrate type. Because targeted sampling designs can often be quickly implemented at a relatively low cost, this type of sampling is often used to meet schedule and budgetary restraints that cannot be met by implementing a statistical design. A comprehensive review of site-specific factors that may influence the location of sampling stations, particularly for large-scale monitoring studies, is provided by Mudroch and MacKnight (1994). U.S. EPA has also developed a computerized sampling design program called the *Fully Integrated Environmental Location Decision Support* (FIELDS) system. This system is a set of software modules designed to simplify sophisticated site and contamination analysis. Each module is a self contained unit that can be applied to a variety of scenarios. When used together, either working through the FIELDS process, or being applied according to a different schedule, the modules offer power and efficiency in the characterization, analysis, and discrete sampling data points to be interpolated into a surface. Important uses of these interpolated surfaces include delineating hot spots, calculating average concentrations, estimating contamination mass and volumes, and developing post-remediation scenarios.

It should be noted that, regardless of the appropriateness of a sampling plan, its ultimate effectiveness will be dependent upon the ability to retrieve the samples. Recovering a complete sediment core representing the desired vertical interval can prove to be infeasible. Representativeness of a sample may be affected by such problems as: core shortening or compression, sample loss during retrieval, sample washout, and inability to determine the sediment surface. The Superfund Innovative Technology Evaluation (SITE) Program has conducted studies to evaluate the capability of samplers to collect representative sediment samples (U.S. EPA, 2000d).

### Science Needs

The National Research Council (1997) discusses the complex factors that must be understood to develop a sediment sampling plan. The distribution of sediment contaminants is determined by complex interactions among meteorological, hydrodynamic, biological, geological, and geochemical factors. Interactions among these factors result in a transport system

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with wide variations, both spatial and temporal. These interactions must be understood in order to specify sampling frequency and location. Sediment transport time scales ranging from hours to months, sometimes disturbed by high-energy storms, must be considered in developing sampling designs. As NRC (1997) notes, designs of sediment sampling strategies increasingly rely on computer-based numerical models. These models fall into four categories: hydrodynamic, sediment and chemical transport, biological toxicity, and ecosystem response. Improved numerical models will facilitate the design of optimal sediment sampling strategies. However, accurate simulations of sediment and chemical transport will also require the development of site-specific formulations.

### 3.2.2 Physical Parameters

Analysis of physical characteristics of sediment provides information that can be used to assess the effects of contaminants on the benthic environment and the water column. Physical analysis of the sediment is generally the first step in the characterization and assessment process. Information describing physical parameters of the sediment is required to understand bioavailability, fate, and transport of sediment contaminants at any site. Physical analysis often includes measurement of parameters such as particle size distribution, total solids, and specific gravity. Methods for measuring sediment physical characteristics have been published and widely used for a number of years. Many of these methods are based on analytical techniques originally developed for soils.

Particle size distribution analysis defines the frequency distribution of size ranges of the mineral particles that make up the sediment (Plumb, 1981; Folk, 1980). Sediment particle size influences both chemical and biological characteristics of the sediment. It is used to normalize chemical concentrations and account for some of the variability found in biological assemblages (U.S. EPA, 1998c) or in laboratory toxicity testing (U.S. EPA, 2000d; Hoss et al., 1999). Particle size is frequently described in percentages of gravel, sand, silt, and clay. Each of these size fractions, however, can be subdivided further so that a more complete characterization of particle sizes can be determined (Puget Sound Estuary Program, 1986). Commonly used sediment particle size methods include: wet sieving (U.S. EPA, 1979; Plumb, 1981; Puget Sound Estuary Program, 1986; Singer et al., 1988), hydrometer method (Day, 1965; Patrick, 1958), pipette method (Guy, 1969; Rukavina and Duncan, 1970), settling techniques (Sandford and Swift, 1971), and X-ray absorption (Duncan and Lattaie, 1979; Rukavina and Duncan, 1970).

Total solids is a gravimetric determination of the organic and inorganic material remaining in a sample after it has been dried at a specific temperature. The total solids values are used to convert concentrations of contaminants from a wet weight to a dry weight basis. Water content of sediment provides useful information for assessments of sediment quality. Methods for determining water content of a sediment are described by Plumb (1981) and Vecchi (1999).

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Specific gravity of a sediment sample is the ratio of the mass of a given volume of material to an equal volume of distilled water at the same temperature (Plumb, 1981). The specific gravity of a sediment sample can be used to predict the behavior (i.e., dispersal and settling characteristics) of sediments. Methods for determining specific gravity are described by Plumb (1981) and Blake and Hartge (1986).

## Science Needs

As noted above, reliable methods are available for measuring the physical parameters of a sediment. Sediment must be collected to measure these parameters. The National Research Council (1997) describes a variety of mechanical methods available to collect vertical sediment column samples for evaluation of physical parameters. Depending on the objectives of a study, sediment samples can be mixed to provide composite samples. This provides an indication of average physical parameter measurements at a site. However, high-resolution spatial data are often needed to fully characterize physical sediment parameters at heterogeneous sites. Obtaining such data requires conducting detailed site surveys with dense sampling. This is a very slow and expensive process that, even with dense sampling, can provide limited spatial resolution.

Sampling is currently conducted using two main types of devices: grab samplers and core samplers. Various grab and core samplers have limitations that can affect cost and time required for sampling. Grab sampler limitations can include: boats, winches, and lines required for operation; limited sampling depth and volume; loss of sample due to incomplete device closure; and sample contamination from metal frame. Core sampler limitations can include: equipment required for operation and lifting, difficulty of deployment and handling, repetitive and time consuming operation and removal of liners, and risk of metal contamination. Improved sampling and data collection techniques could reduce cost and provide improved spatial resolution.

The National Research Council (1997) notes that sediment physical parameters and contaminant concentrations are often interpolated horizontally, resulting in an overestimation of the mass or volume of a contaminated sediment. However, interpolation could also result in an underestimation of the mass or volume of a sediment. Thus, it is important to develop and implement more cost effective assessment technologies to replace coring. The National Research Council further notes that a promising technique for measurement of physical sediment parameters is acoustic sub-bottom profiling. Development of acoustic sub-bottom profiling technology could permit high resolution mapping of acoustic reflectivity, and determination of physical sediment parameters such as porosity, bulk density, and grain size. This technology has the potential to reduce overall sediment assessment costs and increase the spatial resolution of field surveys. In addition to improved field methods for measuring physical sediment parameters, research is needed in two other important areas. Work should also be completed to better understand the effect of geomorphological and physical sediment parameters such as

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sediment texture on the response of benthic organisms exposed to contaminants. Work is also needed to better understand the relationships between bioturbation and physical sediment parameters (such as surface roughness, internal porosity, and physical strength), and the resultant modification of sediment erodability and contaminant transport pathways.

It is recommended that U.S. EPA hold a workshop to identify work necessary to develop methods that could reduce the cost and increase the efficiency and accuracy with which physical parameters can be evaluated at contaminated sediment sites.

### **3.2.3 Chemical Parameters**

Chemical analysis of sediment provides information about chemicals that, if bioavailable, can cause toxicity or bioaccumulate to levels of concern. In addition, chemical parameters such as pH, total organic carbon, and redox potential furnish information to assess bioavailability and contaminant exposure.

U.S. EPA and other agencies have developed analytical methods capable of identifying and quantifying these chemical parameters. However, techniques for analysis of chemical constituents in sediment have some inherent limitations. Interferences encountered as part of the sediment matrix, particularly in samples from heavily contaminated areas, may limit the ability of a method to detect or quantify some analytes. The most selective methods using gas chromatography/mass spectrometry (GC/MS) techniques are often used for nonchlorinated organic compounds because such analysis can avoid problems due to matrix interferences. Gas chromatography/electron capture detection methods are frequently used as the analytical tool for PCB and pesticide analyses because these methods result in lower detection limits. Methods for collection of sediment and interstitial water samples and for analysis of chemical parameters are described in a number of publications (U.S. EPA, 1998c, 1995b, and 2001b).

Many chemical contaminants can persist for relatively long periods of time in sediments where bottom-dwelling animals can accumulate and pass them up the food chain to fish. Therefore, methods are needed for analysis of chemical contaminants in fish tissue. U.S. EPA has published interim procedures for sampling and analysis of priority pollutants in fish tissue (U.S. EPA, 1981); however, official U.S. EPA-approved methods are available only for the analysis of low parts-per-billion concentrations of some metals in fish and shellfish tissues (U.S. EPA, 1991b). Although the U.S. EPA-approved methods for many analytes have not been published, states and regions have developed specific analytical methods for various target analytes (U.S. EPA, 2000c).

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## Science Needs

Although published methods for sampling sediment and quantifying chemical parameters are available, the National Research Council (NRC, 1997) notes that there is growing interest in the use of real-time or near real-time chemical sensors for use in the field. NRC (1997) remarks that these sensors can provide both point measurements and long-term, time-series observations. Development of these technologies is needed for more cost-effective site assessment. Although sensors that measure pH, Eh, oxygen, carbon dioxide, and ammonia are currently available, these sensors are not capable of measuring contaminants of concern in sediments. NRC (1997) identifies fiber-optic sensors as a technology that holds promise for assessment of sediment chemistry. These sensors make use of optical measurements down a fiber, or immobilized membranes or reagents at the fiber tip that reversibly or irreversibly bind with specific analytes, producing a response that can be sensed optically. NRC identifies development of these kinds of technologies as a scientific advancement that would contribute significantly to the development of improved management protocols for contaminated sediment sites.

In addition to the development of field methods for real-time detection of sediment chemical parameters, work is needed to develop more sensitive, low-cost laboratory methods to detect sediment contaminants and chemical parameters that control bioavailability of contaminants. Interferences encountered as part of the sediment matrix, particularly in samples from heavily contaminated areas, may limit the ability of available methods to detect or quantify some analytes. Methods should be developed that minimize the use of hazardous solvents and reagents thereby reducing the exposure of laboratory workers to these chemicals and minimizing the waste which must be disposed of in accordance with Resource Conservation and Recovery Act (RCRA) regulations. Methods must also be developed for sediment contaminants of emerging concern, such as endocrine disruptors, including alkylphenol ethoxylates (APEs) and their metabolites. Work is also needed to develop faster and less expensive methods for analysis of interstitial water. Interstitial water analysis is particularly useful for assessing sediment contaminant levels and associated toxicity. Isolated interstitial water can provide a matrix for both toxicity testing and an indication of partitioning of contaminants within the sediment matrix. In addition to improved laboratory methods for detection of sediment contaminants, improved methods for analysis of chemical contaminants in fish tissue are also needed.

In order to address these science needs, it is recommended that U.S. EPA: 1) develop more sensitive, low-cost laboratory methods for detecting sediment contaminants and real-time or near real-time chemical sensors for use in the field, 2) develop U.S. EPA-approved methods with lower detection limits for analysis of bioaccumulative contaminants of concern in fish tissue, and 3) develop methods for analyzing emerging endocrine disruptors, including alkylphenol ethoxylates (APEs) and their metabolites.

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### 3.2.4 Key Recommendations for Sediment Site Characterization

- A.1 Conduct a workshop to develop a consistent approach to collecting sediment physical property data for use in evaluating sediment stability. (OERR, ORD, U.S. EPA Regions)
- A.2 Develop more sensitive, low-cost laboratory methods for detecting sediment contaminants, and real-time or near real-time chemical sensors for use in the field. (ORD, OERR, GLNPO)
- A.3 Develop U.S. EPA-approved methods with lower detection limits for analysis of bioaccumulative contaminants of concern in fish tissue. (ORD, OERR, OW, U.S. EPA Regions)
- A.4 Develop methods for analyzing emerging endocrine disruptors, including alkylphenol ethoxylates (APEs) and their metabolites. (ORD)

### 3.3 Exposure Assessment

The major human health exposure pathway for contaminated sediments is through the food chain. Body burdens in humans can be measured directly for past exposures from all sources. However, it is more common to measure contaminant concentrations in food fish to estimate human exposure from the dietary pathway. Areas of uncertainty in exposure estimates from this pathway include:

- Fish consumption by sub-populations, such as subsistence fishers, and fish preparation, such as whole fish versus fillet and cooking method.
- Effects of contaminant mixtures, such as weathered PCB mixtures rather than Aroclor mixtures.
- Predictions of the rate and extent of reductions in contaminant concentrations in fish in response to metabolism and natural processes or remedial actions.
- Degree and duration of exposure.

Other potential pathways of human exposure include dermal contact and inhalation exposures from in-place sediments and contact with sediments during removal and *ex situ* management. These pathways have not received as much attention as the food pathway. Science needs include the development of better estimates of dermal exposures and better assessment of circumstances when contaminant volatilization needs to be considered in decision-making.

Ecological receptors can have both direct and food chain exposure to contaminated sediments. Benthic infauna and bottom-feeding fish receive direct exposures to contaminants in sediment interstitial water and overlying water. The thickness of the sediment layer in contact with the biota and the bioavailability of contaminants affect the level of direct exposure to sediment contamination. A better understanding of the thickness of this zone will improve initial

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risk characterization and help in assessing the potential risk reduction achieved by alternative management options.

Higher trophic level fish are exposed to contaminants in the water column, which may derive from the sediment compartment; they are also exposed to bioaccumulative contaminants via their food. Fish-eating avian and terrestrial species are exposed through their food chain. Surrogate measures and models are often used to assess exposures through the bioaccumulation pathway described in Section 3.3.3. Bioaccumulation tools are intended to link simple chemical measurements in the sediment and water column to a resulting body burden in ecological receptors and humans, with an understanding of the acute and chronic risks that the resulting exposure would induce.

### **3.3.1 Bioavailability**

The bioavailability of a contaminant relates total concentration in the sediment, overlying water column, or ambient air to the concentration that affects the ecological or human receptor. Bioavailability depends on the exact chemical speciation of the toxic constituent; the contaminant binding phases in the sediment (e.g., organic carbon for nonionic organic contaminants and acid volatile sulfides for metals); the degree to which the receptor is in contact with it; and the degree to which it is absorbed by the receptor.

Several tools are available to assess bioavailability. Acute and chronic toxicity testing are direct measures of whether or not a contaminated sediment contains enough of the toxicant in an available form to exert a toxic effect. Research by the Office of Research and Development (ORD), in cooperation with the Office of Water (OW), has led to development of a range of toxicity tests described in an earlier section of this plan. Such tests are used in assessing contaminated sediments and in managing dredged material disposal under the Marine Protection, Research and Sanctuaries Act (MPRSA) and Clean Water Act (CWA). These tests can be used to determine whether sediment is toxic, but they do not provide an indication of the chemicals causing the effect.

When unacceptable exposures to toxicants are determined from sediment concentrations, the simplest assumption used is that 100% of the contaminant is available to receptors. This is a conservative assumption appropriate for screening levels.

More realistic and site-specific estimates of bioavailability can be developed using field-measured biota sediment accumulation factors, which relate contaminant concentrations to tissue concentrations to determine what residual sediment concentration will not pose a threat of acute or chronic toxicity.

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An alternative indirect approach is the use of Equilibrium Partitioning Sediment Guidelines (ESGs). This approach uses contaminant concentrations in sediment and other sediment properties to estimate the pore water concentration of contaminants at chemical equilibrium. The pore water concentration is then correlated with the concentration available to the aquatic organism and can be compared to various reference values for acute or chronic toxicity. ESGs can be used to determine which contaminants in sediment might be exerting a toxic effect demonstrated in whole sediment toxicity tests. They can also be used to help establish unacceptable levels of toxic contaminants in sediment.

### 3.3.2 Bioaccumulation Potential

Some sediment contaminants exert toxic effects by being accumulated to greater degrees in successively higher trophic levels. Thus, a sediment contaminant concentration that poses no direct acute or chronic toxicity to aquatic biota or humans via direct exposure may be magnified through the food chain so that species eating fish or aquatic wildlife are exposed to an unacceptable toxicant dose.

The most direct measure of bioaccumulation is measurement of the toxicant in the tissues of the receptor (Figure 3-1). Direct measurement is ideal because it includes all sources of exposure and accounts for elimination and metabolism. Bioaccumulation test method protocols have been developed for freshwater oligochaetes and marine polychaetes and bivalves (U.S. EPA, 2000d; Lee et al., 1989). The National Research Council (2001a) recommends this method for PCBs: *An assessment of present exposure is best addressed through direct measurement of PCBs in specific organisms or in their diet.*

**Figure 3-1. Methods for Estimating Bioaccumulation**

- *Field-measured bioaccumulation factor* - direct measurement of the relationship between water concentrations and tissue concentrations of the toxicant.
- *Field-measured biota-sediment accumulation factor* - direct measurement of the relationship between sediment concentrations and tissue concentrations of the toxicant.

The direct measurement method is referred to as a field-measured bioaccumulation factor (BAF) for water/organism interactions and a field-measured biota-sediment accumulation factor (BSAF) for sediment/organism interactions. The BAF is appropriate for all chemical stressors, while the BSAF is appropriate for nonionic organic compounds and ionic organics that partition to lipids and organic carbon in similar ways. Although direct measurement can be expensive and difficult, it is commonly used in assessments of contaminated sediment sites. There are uncertainties if bioaccumulation is measured in food sources because consumption rates by higher trophic levels are not always well-known for ecological predators and humans,

particularly human sub-populations from fishing cultures. Therefore, OW and ORD have collaborated on extensive research to provide alternative estimates that relate contaminant concentrations in sediments and water to the concentrations that would consequently occur in various species.

Laboratory tests can be used to assess bioaccumulation by freshwater and marine benthic invertebrates. Methods are available for freshwater *Diporeia* spp., *Lumbriculus variegatus*, and mollusks and marine species. OW has published a compendium of methods for measuring bioaccumulation of sediment-borne toxicants in freshwater (U.S. EPA, 2000d).

Deployed organisms also can be used to measure current exposures to sediment-borne toxicants. These measures are very useful in determining baseline exposures and responses to remedial actions. However, the linkage between caged organism uptake and dietary exposure of higher trophic levels is uncertain. A further confounding factor exists for persistent and bioaccumulative toxicants such as PCBs and PAHs. These complex mixtures change over time through weathering and are found in different mixtures in source sediments and receptor tissues.

The current state-of-the-practice is to use direct testing and models to estimate the direct dose delivered to the lowest trophic level in a food web and the food-delivered dose to successively higher trophic levels. Models range from simple to complex. Empirical models use partitioning coefficients (BAFs or BSAFs) to link sediment concentrations with tissue levels in organisms. More complex models use mechanistic models of uptake, metabolism, and excretion, along with feeding patterns to estimate the tissue burdens for fish, birds, and mammals.

The approaches described above provide several different ways to assess exposure of ecological and human receptors to sediment-borne contaminants. Each of the estimation approaches can cause disagreements among affected parties, ranging from the theoretical soundness of alternative approaches to the values selected for exposure duration and dietary composition. Even with the direct measurement of contaminants in receptor tissues, arguments can be made about the relative importance of sediment contamination relative to other sources. Validation of models is hindered by a paucity of data sets that overcome the natural variability of ecological receptors. Research on monitoring may provide additional tools to measure bioaccumulation in receptors.

### **3.3.3 Fate and Transport Modeling**

Aquatic sediments are a sink for contaminants from a wide range of point and nonpoint sources. But the “sink” is connected to ecological and human receptors through a variety of mechanisms: partitioning to the overlying water column and air; uptake by organisms and accumulation or magnification in the food chain; chemical and biological alteration; dilution and dispersion; bulk sediment transport; and burial by fresh sediments. For non-degradative

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processes, it may be necessary to evaluate the transport and fate of the contaminant in the short-term and the long-term. For example, a persistent and bioaccumulative toxicant that is diluted and dispersed in a river over the short-term may become part of a longer-term biogeochemical cycle over a much larger region. The National Research Council (NRC, 2001a) made two recommendations for research specifically related to PCB-contaminated sediments:

1. *A better understanding of the contribution of PCB-contaminated sediments to the total global burden is needed.*
2. *The role of global cycling of PCBs in assessing the PCB problem at a specific site should be considered.*

Although the NRC report specifically addressed PCBs, these recommendations are also applicable to other persistent and bioaccumulative toxicants such as mercury and some pesticides.

The current state-of-the-practice is to apply one or more of a suite of mathematical models to simulate the important processes. Fate and transport modeling can be highly controversial because various models, assumptions used in the models, and selection of input parameters can lead to very different conclusions about present risk and how protective various remedial alternatives will be.

The fate of organic contaminants in sediments may include degradation via chemical and biologically-mediated pathways. The mechanisms, rates, and endpoints of degradation processes need to be better understood to assess both natural recovery and active remedies that are intended to enhance contaminant degradation. NRC (2001a) noted that anaerobic dechlorination may have a threshold value. This implies that degradation may proceed from higher concentrations toward the threshold value and then become negligible; models need to account for such non-linear behavior.

Contaminant transport in sediments and overlying waters is critical to assessing both present risk and the performance of all remedies. Contaminants can be transported by diffusion and dispersion within bed sediments, advection from upward groundwater movement, bulk sediment movement, movement of suspended sediments, and dissolution into the overlying water. Contaminants can enter and leave the system through landscape erosion, atmospheric deposition, and volatilization. All of these processes are active in sediment systems and determine how biotic exposure changes over time. The wide range of transport mechanisms contributes to uncertainty in the characterization of sediment sites as well as estimates of present risk. Active capping and the natural process of burial by cleaner sediments can only be effective over the long-term if contaminant transport by diffusion, advection, and bioturbation are slow enough that sediments and the overlying water column remain at safe levels. These remedies also depend on the long-term stability of the system with respect to bulk sediment movement by

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natural hydrodynamics and human intervention, such as dam removal, navigation dredging, boat traffic, and so on.

The role of uncertainty in fate and transport modeling needs to be addressed so that stakeholders understand how sure we are of existing risks and the risk reduction achievable by remediation. It is critical that the contaminant transport models link smoothly with biological uptake and trophic transfer models to obtain an accurate assessment of present risks and risk reductions achievable by management alternatives.

### **Science Needs**

The science needs associated with exposure assessment relate to refining our understanding of the important pathways of exposure and improving the tools used to measure and model how contaminants cycle within the system. The complexity of the tools applied to specific sites should be commensurate with the risks and costs of proposed decision-making and consistent with the National Research Council recommendation (NRC, 2001a). The use of different tools at different sites or under different authorities should be integrated so that consistent decisions can be made to protect the environment and potential ecological or human receptors. Because contaminated sediment is a mobile medium and contaminants within sediment can migrate into other media, understanding all the important fate and transport processes is a key step in assessing the risk and estimating the potential effectiveness of various remedial actions.

#### **3.3.4 Key Recommendations for Exposure Assessment**

- B.1 Develop a tiered framework for assessing food web exposures. (ORD, OW, OERR, U.S. EPA Regions)
- B.2 Develop guidance and identify pilots for improving coordination between TMDL and remedial programs in waterways with contaminated sediments. (OW, OSWER, U.S. EPA Regions)
- B.3 Develop and advise on the use of the most valid contaminant fate and transport models that allow prediction of site-specific exposures in the future. (ORD, OERR, OW, U.S. EPA Regions)
- B.4 Develop a consistent approach to applying sediment stability data in transport modeling. (ORD, OERR, OW, U.S. EPA Regions)

### **3.4 Human Health Effects and Risk Assessment**

Contaminants in sediments can present risks to humans through direct contact with the sediment (inhalation of particulates or gases, ingestion, dermal contact) or indirect exposure pathways (ingestion of fish, wildlife, or plants which have accumulated contaminants from

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sediments). Health effects may occur at the point of contact, e.g., skin or lung, but will most often occur in response to contaminants or their metabolites circulating internally (the internal dose). The FIELDS software tools contain a human health module for analyzing the human health impact of contaminated sediments via dermal, ingestion, and inhalation pathways. Further improvements underway on this module for FY02 include refinements of existing exposure pathway models.

Sediments are often environmental sinks for multiple contaminants and can act as a source of exposure to multiple contaminants, some of which may act by a common mechanism of toxicity. PCBs exist as a mixture whose components, individual PCB congeners, change in concentration over time. Risk assessments should consider the additive or cumulative effects of all contaminants. Some contaminants may pass through the placenta to the developing fetus or may be passed to nursing infants. Therefore, risk assessments should consider sensitive and highly exposed subpopulations, particularly children, and focus on neurological and developmental effects.

Health risk assessments need to evaluate the mode of action for contaminants and all detailed mechanistic data which may be available. Cancer risk assessment for dioxins, furans, and 'dioxin-like' PCB congeners focuses on the chemical's binding to a particular cellular receptor (Ah) and subsequent responses. Likewise, many contaminants bind to the endocrine receptor, raising assessment concerns for endocrine disruption in both humans and wildlife.

Some exposures to sediments may be intermittent or of limited duration. Risk assessments should match these exposure data with subchronic toxicity data. These data are rarely available. More information is needed on the toxicity of newly recognized contaminants such as potential endocrine disruptors.

### Science Needs

Advances in any of the above subjects would result in an improved understanding of the health effects of exposure to contaminated sediments. Several of these areas are extremely important for assessing other environmental problems as well. Needs particularly important to sediments include:

- Speciation and characterization of individual contaminants in sediment or biological samples to evaluate mode of action and individual chemical contributions to risk. Examples include distribution of individual PCB congeners (NRC, 2001a); dioxins, furans, and dioxin-like PCBs; PAHs; and mercury species.
  - Determining interactions among multiple contaminants found in sediments and the resulting impacts on site-specific risk assessment (NRC, 2001a).
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- Relating the results of bioaccumulation studies in animals or other models to doses in humans.
- Studies of mode- and mechanism-of-action for species and mixtures most often found in sediments, particularly focusing on chronic or sub-chronic systemic effects.
- Developing biomarkers of effect (toxicity) and relating these to measurable toxic endpoints.
- Evaluating the reproductive toxicity of endocrine disruptors and other newly emerging contaminants of concern such as APEs.
- Revise methods for estimating dermal exposures and risk from sediments.

### **3.4.1 Key Recommendations for Human Health Effects and Risk Assessment**

- C.1 Develop guidance for characterizing human health risks on a PCB congener basis. (ORD, OERR, U.S. EPA Regions)
- C.2 Develop sediment guidelines for bioaccumulative contaminants that are protective of human health via the fish ingestion pathway. (ORD, OERR, OW, U.S. EPA Regions)
- C.3 Refine methods for estimating dermal exposures and risk. (ORD, OERR, U.S. EPA Regions)
- C.4 Evaluate the toxicity and reproductive effects of newly recognized contaminants, such as alkylphenol ethoxylates (APEs) and other endocrine disruptors and their metabolites on human health. (ORD)

## **3.5 Ecological Effects and Risk Assessment**

### **3.5.1 Ecological Screening Levels**

Numerical screening levels or sediment quality guidelines based upon concentrations of contaminants in sediment that are associated with potential adverse effects have been proposed by a number of investigators and jurisdictions around the world (Chapman, 1989; Long and Morgan, 1991; Long, 1992; MacDonald et al., 1996; U.S. EPA 1992b, 1996b, and 1997a; Macdonald et al., 2000; Field et al., 1999). Screening values are needed by U.S. EPA, states and tribes, and other Federal agencies to: 1) help prioritize sites and areas for further investigation, 2) help identify causative contaminants when toxicity is indicated by bioassays or other tools; and 3) develop Total Maximum Daily Loads (TMDLs) and National Pollution Elimination Discharge System (NPDES) permit limitations.

One approach to the derivation of numerical values has focused on evaluation of the available toxicity data to establish associations between individual chemical concentrations in sediments and adverse biological effects. This empirical or correlative approach was originally developed by the National Oceanic and Atmospheric Administration (NOAA) using sediment chemistry data collected under the National Status and Trends Program (Long and Morgan, 1991;

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Long, 1992). The empirical guidelines approach was adopted, with some modifications, by the Florida Department of Environmental Protection (MacDonald, 1994; MacDonald et al., 1996) and the Canadian Council of Ministers of the Environment (CCME, 1995; Smith et al., 1996) to support the development of guidelines in the State of Florida and in Canada. Additional data available in the published literature and collected through U.S. EPA's Assessment and Remediation of Contaminated Sediment (ARCS) program have been used to further refine the empirically derived guidelines (Ingersoll et al., 1996). Although empirically derived sediment quality guidelines have in many cases accurately predicted sediment toxicity, a number of limitations have been associated with this approach (MacDonald et al., 1996). The correlative approach does not support the quantitative evaluation of cause and effects relationships between contaminant concentrations and biological responses. Because the approach is based on associations between contaminant concentrations and biological responses, various factors other than the concentrations of the contaminant under consideration could have influenced the actual response observed in any investigation. In addition, the guidelines developed using this approach do not address either the potential for bioaccumulation or the associated adverse effects of bioaccumulation on higher trophic levels. The recent National Research Council report on PCB-contaminated sediments (NRC, 2001a) stated that, at least for PCBs, "ERM [effects range median] and ERL [effects range low] values are not deemed to be reliable and should not be used for ERAs [ecological risk assessments]."

Another approach used by U.S. EPA is the equilibrium partitioning (EqP) approach to develop draft Equilibrium Partitioning Sediment Quality Guidelines (ESGs). This approach focuses on predicting the chemical interaction among sediments, interstitial water, and the contaminants. Studies have indicated that interstitial water concentrations of contaminants appear to be better predictors of biological effects than bulk sediment concentrations. U.S. EPA based the ESGs on EqP theory, which is a conceptual approach for predicting the bioavailability of sediment-associated chemicals and their toxicity. The theory assumes that sediment-associated chemicals partition to a state approximating equilibrium between three phases: the interstitial (pore) water, the binding phases in sediment which limit bioavailability (i.e., organic carbon for nonionic organic chemicals and acid volatile sulfides for divalent metals), and the biota. Under this assumption, the pathway of chemical exposure (i.e., respiration of interstitial water or ingestion of sediment) is not important, because the activity of the chemical is the same in each equilibrated phase. If the chemical concentration in any one phase is known, then the concentration in the others can be predicted. Thus, EqP theory, enabling prediction of interstitial water concentration from the total sediment concentration and the relevant sediment properties (i.e., organic carbon), can be used to quantify the exposure concentration for an organism. However, U.S. EPA also notes that equilibrium partitioning theory does not address potential food chain effects of bioaccumulative sediment pollutants. Details on the ESG methodologies and chemical-specific ESGs can be found in the following documents:

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- *Eco Update. Intermittent Bulletin Volume 3, Number 2 – Ecotox Thresholds. U.S. EPA 540/F-95/038 (U.S. EPA, 1996b).*
- *Draft - Technical Basis for the Derivation of Equilibrium Partitioning Sediment Guidelines (ESGs) for the Protection of Benthic Organisms: Nonionic Organics (U.S. EPA, 2000b).*
- *Draft - Equilibrium Partitioning Sediment Guidelines (ESGs) for the Protection of Benthic Organisms: Metal Mixtures (Cadmium, Copper, Lead, Nickel, Silver, and Zinc) (U.S. EPA, 2000a).*

Although theoretically derived screening levels (e.g., those based on the EqP approach) can be used to predict levels that are safe, they are less accurate in predicting when these concentrations in the field will result in unacceptable risks to exposed aquatic organisms. This is not an issue at Superfund and the Resource Conservation and Recovery Act (RCRA) Corrective Action sites, because site-specific sediment toxicity tests or bioassessments can be performed on-site or using site-collected sediments to empirically determine levels of effects. It is not clear, however, what the relationship is between mortality rate in a sediment test with *Hyallela* or reduction in species diversity and expected significant impacts on ecosystem function or structure in the contaminated waterbody. Additional work should be undertaken to improve existing screening values and develop new ones for bioaccumulative contaminants.

The FIELDS software tools contain an ecological risk module, peer reviewed by U.S. EPA Ecological Risk Assessors Forum, which includes screening values and can be used for analyzing the impact of contaminated sediments on ecological receptors. Further refinements underway on this module for FY02 include the addition of wildlife exposure models and the ability to evaluate risks based on tissue concentrations.

## Science Needs

U.S. EPA's Science Advisory Board (SAB) and others have identified a number of science needs to further support regulatory use of the Agency's ESGs and other chemical-specific screening values and sediment quality guidelines (SAB, 1992 and 1996). These science needs include:

- Field and laboratory studies to evaluate the accuracy of chemical-specific sediment quality guidelines. These could include new studies and the use of existing data from contaminated sites where both contaminants and benthic community data are available. Sublethal sediment toxicity tests (*in situ* studies, laboratory studies of field-collected sediment, and spiked-sediment laboratory studies) using a range of species including benthic fish and algae, long-term studies of population dynamics, and colonization studies are examples of sensitive tests that could be used to further validate sediment quality guidelines. Additional work should be undertaken to evaluate the range of
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sediment types to which sediment guidelines can be applied. Field validation of these guidelines in different sediment types would help define the appropriate conditions for applying the guidelines.

- Studies of chemical concentrations in interstitial water from natural sediment samples are needed. These values can be compared to predicted ESG values for the same sediments.
- For ESGs, additional research can evaluate the relative significance of binding factors other than organic carbon and acid volatile sulfides that may affect bioavailability of contaminants.
- Bioaccumulation from food and kinetic limitations on contaminant bioaccumulation should be further evaluated to determine their relevance for both equilibrium and non-equilibrium conditions. Additional work should be conducted to determine whether metals guidelines can be used to define conditions where sediment sorbed metals can be bioaccumulated by benthic organisms. These investigations can provide additional insight into the contributions of adsorbed or digested material to total exposure.
- In addition to diet, habitat requirements of benthic infaunal and other sediment-dwelling organisms may cause them to be exposed to higher concentrations of contaminants than those measured in bulk sediments. Investigations should be undertaken to determine the importance of contaminant exposure routes that are not now explicitly considered. For example, preferential sorting of particulates during tube building may be a route of exposure to contaminants that could be considered in applying sediment quality guidelines.
- There has been considerable discussion about whether sediment quality guidelines should comprise a range of values reflecting uncertainty, or the current point estimates. Recent modeling work has attempted to address this by using the probability of effects to define sediment quality guidelines. The use of a range of values or the development of improved estimates of uncertainty could be considered.
- Although U.S. EPA has conducted research to develop mixtures guidelines for PAHs and metals, additional work should be completed to understand how mixtures of contaminants in sediments should be handled.
- Work is needed to develop a better understanding of the time and space scales over which sediment quality guidelines or other assessment tools are valid. Organisms are major contributors to sediment spatial heterogeneity and may affect oxygen penetration depth across spatial gradients. Sediment mixing affects redox regimes, which can affect the bioavailability of redox-sensitive chemicals. It is necessary to understand how sediment biogeochemistry could affect the application of sediment quality guidelines.

### **3.5.2 Ecological Indicators**

Historically, sediment monitoring programs have used benthic community studies as indicators of the effects of sediment contaminants on aquatic ecosystems. An assessment of benthic community structure typically involves a field survey that includes sorting and

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identification of organisms and analysis of the numbers of taxa, individuals, and biomass in each sample. At many sites, the objective of the benthic community survey is to determine if there are unacceptable risks to the communities of organisms that inhabit those sediments. Many different benthic community measures have been used as ecological indicators such as: species diversity indices; biotic indices; indicator organisms; species richness measures; enumeration of specific abundances of taxa present; indices measuring similarity between benthic communities at reference and study sites; community function measurements based on habitat; trophic structure and other ecological measures; and statistical approaches applied to determine whether the benthic community at a study site varies from reference or other sites. The major limitation associated with the use of these indicators is difficulty relating them to the presence of individual chemicals or other stressors.

### Science Needs

The development of new indicator methods for measuring risks from sediment contaminants will lead to more effective assessment and characterization of contaminated sites. Additional research should be conducted to develop new indicator methods at all levels of biological organization (molecular, cellular, organismal, population, and community). It is important that these biological responses can be linked to known chemical stressors. Cellular and biochemical measurements can be used to indicate the bioavailability of sediment contaminants to establish levels of exposure, and to facilitate fate and transport modeling of the contaminants. A number of specific science needs have been identified to link sediment contaminants and other stressors with biological impairment. These include:

- Development and assessment of statistical techniques to associate sediment contaminants with community-level responses.
  - Development of methods to characterize exposure to individual stressors and predict exposure to contaminant mixtures.
  - Development of whole sediment toxicity identification methods.
  - Development of tools to determine genetic impairment caused by contaminants in sediment.
  - Development of diagnostic indicators for emerging chemicals such as endocrine disruptors.
  - Development of mechanistic ecosystem models and a better understanding of benthic community structure and function.
  - Development of methods to measure spatial and temporal variation in structural and functional properties of benthic communities, and an understanding of how this variation affects prediction and detection of impacts.
  - Determination of the cause-effect connection between sediment contamination and of behavioral responses, and the relevance of behavioral responses.
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### 3.5.3 Direct Toxicity to Aquatic Biota

Studies at contaminated sediment sites have demonstrated that high concentrations of contaminants have resulted in direct toxicity to benthic invertebrates and to reductions in fish and wildlife populations. At some sites that are heavily contaminated from past mining operations, heavy rain events have resulted in acute lethality of salmonids due to short-term pH-induced increases in metal solubility in the water column.

Biological sediment testing has become an effective assessment tool that provides direct, quantifiable evidence of biological consequences of sediment contamination. Sediment tests can be used to: 1) determine the relationship between toxic effects and bioavailability, 2) investigate interactions among chemicals, 3) compare the sensitivities of different organisms, 4) determine spatial and temporal distribution of contamination, 5) evaluate dredged material, 6) rank areas for cleanup, and 7) set cleanup goals.

A variety of standard biological test methods have been developed for assessing the short-term and long-term toxicity of contaminants associated with freshwater and marine sediments using amphipods, midges, polychaetes, oligochaetes, mayflies, and cladocerans. These toxicity tests provide measures of several different endpoints including survival, growth, behavior, and reproduction. Sediment toxicity identification evaluation (TIE) procedures have also been used to identify toxic compounds in sediment samples containing mixtures of chemicals.

### Science Needs

Although a number of sediment toxicity test methods have been standardized, protocols using new test species should be developed to provide tests of greater sensitivity. It will also be necessary to standardize test methods using species that inhabit different geographic ranges and habitat types. Additional work will be necessary to:

- Develop a better understanding of how sediment can be manipulated before, during and after tests without inappropriately affecting test results.
  - Establish appropriate physical test conditions, feeding regimes, test duration, and test initiation or termination procedures.
  - Develop a better understanding of how geophysical properties of sediment affect test results.
  - Complete additional work to understand the sensitivity of test species to major classes of contaminants. This information can aid in species selection and test interpretation.
  - Conduct additional verification and validation studies of toxicity test methods. Validation studies could be conducted by evaluating bioassay response to sediments collected along a natural pollution gradient and comparing results to benthic community studies and *in situ* test results.
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- Identify and standardize formulated sediment and sediment spiking techniques;
- Develop tests with amphibians and reptiles.
- Develop and standardize higher level tests (e.g., microcosms and mesocosms).
- Develop better understanding of exposure-time relationships in chronic whole sediment toxicity tests.
- Develop field-based methods to assess biological effects of contaminated sediments.

### **3.5.4 Ecological Significance and Population Models**

In an ecological risk assessment, it is important to clearly define and describe ecological significance and to determine what levels of population and community effects are generally acceptable; e.g., will a twenty percent reduction in a specific endpoint still sustain a functioning, healthy ecosystem? How does U.S. EPA determine that: 1) the observed or predicted adverse effects on a structural or functional component of the site's ecosystem is of sufficient type, magnitude, areal extent, and duration that irreversible effects have occurred or are likely to occur, and 2) these effects appear to exceed the normal changes in the structural or functional components typical of similar unimpacted ecosystems?

### **Science Needs**

- Develop predictive models for determining the potential population level effects; e.g., how much sediment toxicity is needed before one can predict that there will be significant effects on the population of concern. How many bass or mink or kingfishers can be affected before there will be an impact on the ability of the population of biota to sustain itself at a healthy level in the area impacted by the site?
- Develop a method for estimating depth of bioturbation for benthic macro-invertebrates. Certain benthic macro-invertebrates that colonize on caps build or live in burrows or tunnels in the sand/sediment cap environment. In order to evaluate the potential impact on these aquatic food chain organisms, we need to identify the depth and extent of benthic bioturbation impacts in a cap.
- Potential benthic macro-invertebrate cap attraction. Caps often are of a non-indigenous fill material or sand or are anchored with stone. Will use of different materials reduce colonization times? Will it attract other, less desirable organisms and non-native communities?

### **3.5.5 Key Recommendations for Ecological Effects and Risk Assessment**

- D.1 Develop sediment guidelines to protect wildlife from food chain effects. (ORD, OERR, OW, U.S. EPA Regions)
  - D.2 Develop additional tools for characterizing ecological risks. (ORD, U.S. EPA Regions, OW)
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- D.3 Develop guidance on how to interpret ecological sediment toxicity studies (lab or *in situ* caged studies); and how to interpret the significance of the results in relation to site populations and communities. (OW, ORD, OERR, U.S. EPA Regions)
- D.4 Acquire data and develop criteria to use in balancing the long-term benefits from dredging vs. the shorter term adverse effects on ecological receptors and their habitats. (ORD, OERR, U.S. EPA Regions)
- D.5 Conduct field and laboratory studies to further validate and improve chemical-specific sediment quality guidelines. (OW, ORD)
- D.6 Continue developing and refining sediment toxicity testing methods. (ORD, OW, U.S. EPA Regions)
- D.7 Develop whole sediment toxicity identification evaluation procedures for a wide range of chemicals. (ORD, OW)

### 3.6 Sediment Remediation

A sediment remedial alternative is a technology or combination of technologies used to reduce the impact of contaminated sediments on human health and the environment. Alternatives can span a wide range of complexity and technological ingenuity. The simplest alternatives might employ only a single component (i.e., *in situ* capping). However, more complex alternatives may involve several different technologies and various project components (U.S. EPA, 1994). For the more complex alternatives, it is important to match complementary components in order to obtain an efficient remedial design (e.g., hydraulic dredging may not be the best choice for sediments that will be disposed of in a landfill due to the "no water in landfills" rule).

Due to all the confounding factors involved in sediment remediation, it is difficult to capture all the complexities of the state of the science in sediment remediation in only a few short pages. However, the subsections below provide a summary of the current state of sediment remediation technology, identification of problems, and a discussion of key research gaps.

#### 3.6.1 Natural Recovery/Bioremediation

Natural recovery involves leaving contaminated sediments in place and allowing ongoing chemical, physical, and biological aquatic processes to contain, destroy, or otherwise reduce the bioavailability of contaminants. No actions are required to initiate or continue the natural recovery process (NRC, 1997). Although natural recovery has been the strategy of choice at only a few contaminated sediments sites, the absence of timely remedial activities at many sites has made natural recovery the *de facto* remediation of choice at these sites. Case studies are identified in the National Research Council (1997) document.

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There are a plethora of resources available that provide more information on the natural recovery and bioremediation of contaminated sediments. However, there is still an ongoing debate regarding the viability of using natural processes or engineered biological processes to remediate contaminated sediments, especially those contaminated with heavy metals and chlorinated organics: "Using bioremediation to treat in-place [contaminated] sediments, although theoretically possible, requires further research and development because it raises a number of significant microbial, geochemical, and hydrological issues [including transport by large-scale storm events] that have yet to be resolved" (NRC, 1997).

Additionally, while the "natural capping" and resulting sequestration of sediment contaminants from natural deposition may occur at a faster "average" rate than the ongoing biological breakdown, large scale storm events may result in the unfortunate circumstance, as seen at the Saginaw River, Michigan, of hot-spot contamination being dispersed over a large area where it would be difficult to remove or remediate.

The NRC (1997) document offers the following science needs for further research.

### Science Needs

- Develop scientific principles to describe the process of natural recovery.
- Perform a literature survey to determine the level of effectiveness at natural recovery sites.
- Develop accepted measuring protocols to determine *in situ* chemical fluxes from bed sediments into the overlying water column.
- Develop protocols for assessing the relative contribution of the five or more mechanisms for chemical releases from bed sediments (including mass transport of sediments and contaminants by large-scale storm events).
- Determine the mechanisms for measuring the bioavailability of sorbed contaminants and the effect of sediment aging.
- Determine the rate and/or presence of anaerobic degradation processes in near-shore, mostly anoxic sediments.
- Conduct additional laboratory, pilot-scale, and field-scale demonstrations of the effectiveness of biological treatments.
- Explore the possibility of combining *in situ* bioremediation with *in situ* capping.

#### 3.6.2 *In situ* Capping

"*In situ* capping is the controlled, accurate placement of a clean, isolating material cover, or cap, over contaminated sediments without relocating the sediments or causing a major disruption of the original bed" (NRC, 1997). U.S. EPA's Great Lakes National Program Office and U.S. EPA Region 5 have coordinated with U.S. Army Corps of Engineers and U.S.

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Geological Survey in the production of two guidance documents on *in situ* capping (U.S. EPA, 1998d, and in prep.). Capping attempts to limit the adverse impacts of sediment contamination by providing a barrier to prevent contact between aquatic organisms and the contaminated sediments. Capping may also prevent downstream transport of sediments and their associated contaminants.

The design and installation of conventional sediment caps is fairly straight-forward and well understood, including the numerous cap placement technologies (tremie tube, submerged diffuses, and others) described by U.S. EPA (1998d). However, the long-term effectiveness of this alternative has not been well researched, although the National Research Council (NRC, 2001a) documents *in situ* capping case studies that have been completed in Hamilton Harbor, Canada and the St. Paul Waterway in Tacoma, Washington. Reports documenting results of these operations can be found in Zeman and Patterson (1997) and Parametrix (1999), respectively. Additionally, many entities are now beginning to discuss more complex sediment cap designs, including the use of zero-valent iron or biological treatment mechanisms in the cap design.

### Science Needs

- Analyze data from historical and ongoing field applications to determine capping effectiveness (NRC, 1997).
- Research and/or develop technologies to control contaminant releases during cap placement (NRC, 1997).
- Testing to simulate and evaluate the consequences of episodic mixing (e.g., anchor penetration and major flood/storm events) (NRC, 1997).
- Determine the impacts of advective transport (i.e., groundwater flow) on the transport of contaminants through the cap.
- Develop and evaluate the use of innovative cap designs that incorporate chemical and/or biological treatment technologies.
- Assess the uncertainties associated with cap performance predictions.

#### 3.6.3 *In situ* Treatment

*In situ* treatment involves the active manipulation of in-place sediments to enhance the breakdown or prevent the transport (e.g., immobilization) of contaminants. Potential technologies include: *in situ* immobilization, *in situ* chemical treatment, *in situ* freezing, *in situ* geo-oxidation, and *in situ* vitrification (NRC, 1997).

Immobilization technologies are likely to be based on the concepts of solidification and immobilization. The applicability of these processes to fine-grained sediments with high water content has yet to be demonstrated. Potential problems include: inaccuracies of *in situ*

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placement, erosion, temperature increases during curing, and increases in sediment volume (NRC, 1997).

Researchers at the Canadian National Water Research Institute have developed and demonstrated equipment capable of injecting chemical solutions into sediments at a controlled rate (U.S. EPA, 1994). However, the applicability of *in situ* chemical treatment appears to be limited because of interference between various classes of contaminants and the possibility of mobilizing metals in the process of oxidizing organics (NRC, 1997). The National Research Council (NRC, 2001) states that "no effective *in situ* delivery system has yet been developed for [delivering required nutrients, substrates, or reagents to] contaminated sediments."

The use of *in situ* freezing and *in situ* vitrification can be quickly dismissed based on high cost and limited effectiveness. Freezing by injection of molten sulfur has the same limitation as *in situ* solidification. *In situ* vitrification has been demonstrated on soils, but the high water content of sediments would require local site dewatering and the construction of a vapor recovery system (NRC, 1997). The NRC (2001a) documents the difficulties encountered on an *in situ* treatment project in Manitowoc Harbor, Wisconsin. There are many difficulties associated with the application of *in situ* technologies to contaminated sediment deposits. Many of these problems are based upon the application of known processes to the high volumes of low-concentration sediment generally found in the field. In addition, many sediment deposits are both heterogeneous and fine-grained, making the uniform application of treatment amendments difficult.

The use of ElectroChemical Geoxidation (ECGOx) is being considered for a pilot-scale demonstration in Puget Sound, Washington. Two additional *ex situ* pilot-scale sediment treatment projects using ECGOx are also in the planning stages. The ECGOx process uses low-voltage, low-amperage, alternating current/direct current to sustain a reduction-oxidation reaction between two electrodes placed in the sediments. This redox reaction results in the mineralization of organic compounds. Target compounds for this treatment include PAHs, PCBs, and other organics (CDM, 1986). Additionally, by making adjustments to the current applied to the system, ECGOx can mobilize inorganic contaminants and plate them to the cathode and anode ends of the electrodes. Unconfirmed data provided by the vendor indicate the success of ECGOx in addressing PAHs, PCBs, and mercury contamination in soils.

### Science Needs

- Additional extensive research of most *in situ* treatment would be required and is probably not justified based on the limited applicability and effectiveness of current technologies (NRC, 1997).
  - U.S. EPA should oversee and critically evaluate the three *in situ* and *ex situ* ECGOx pilot-scale demonstrations planned for the U.S. in 2001 and 2002 to determine if
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additional studies are justified (The Great Lakes National Program Office, U.S. Army Corps of Engineers, several private companies, U.S. EPA's Superfund Innovative Technologies Evaluation Program, U.S. EPA Region 2, and U.S. EPA Region 10 are involved in the evaluation and demonstrations currently being discussed).

- Continue an open dialogue with international agencies and technology vendors and perform literature reviews to keep abreast of any advances in *in situ* treatment technologies.

#### 3.6.4 Dredging/Removal

"Efficient hydraulic and mechanical methods are [readily] available for the removal and transport of sediments for *ex situ* remediation or confinement" (NRC, 1997). Additionally, promising technologies for precision control include electronically positioned dredge-heads and bottom-crawling hydraulic dredges. The latter may offer the capability of dredging in depths beyond the standard maximum operating capacity of conventional dredges (NRC, 1997). Finally, many innovative mechanical (e.g., environmental clamshell) and hydraulic pumps (e.g., Eddy pump, PNEUMA pump) are available that advertise reduced sediment resuspension, increased solids content of dredged material, and/or other performance enhancements. Adequate research and data are not available to evaluate all of these claims. Hayes (1989) noted that the operation of the dredge and experience of the dredge operator have a profound effect on the rate of sediment re-suspension. Furthermore, recent monitoring at dredging sites has focused on the short-term impacts and contaminant losses associated with dredging operations. U.S. EPA (1996a) presents a good general framework for estimating contaminant losses from all components of the dredging and disposal process. Additionally, the USGS (Steuer, 2000) presents a case study for monitoring short-term impacts for a dredging project on the Fox River, Wisconsin.

#### Science Needs

- Performance evaluation for innovative dredging equipment.
- Evaluate the performance of low re-suspension dredges capable of removing sediments at near *in situ* densities (NRC, 1997).
- Enhanced capabilities for precision removal of sediments (NRC, 1997).
- Increased monitoring before, during, and after dredging to determine short-term impacts and long-term improvements due to dredging projects.

#### 3.6.5 *Ex situ* Treatment Technologies

Numerous *ex situ* treatment technologies have undergone bench- and pilot-scale demonstrations. The results of these studies are documented in numerous reports including U.S. EPA's Assessment and Remediation of Contaminated Sediments (ARCS) program reports

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(<http://www.epa.gov/glnpo/arcs/>), International Navigation Association (PIANC) proceedings, Superfund's Innovative Technology Evaluation (SITE) programs (<http://www.epa.gov/ORD/SITE/>), and other documents. *Ex situ* treatment is generally more promising than using the same technology *in situ*, because conditions can be more tightly controlled in contained facilities. Chemical separation, thermal desorption, and immobilization technologies have been employed successfully but are expensive, complicated, and limited to treating certain types of sediments and/or contaminants. Because of the high unit costs, thermal and chemical destruction techniques do not appear to be cost-effective, near-term approaches for remediating large volumes of contaminated dredged material (NRC, 1997).

Following up on the work conducted under the ARCS Program, U.S. EPA Region 2 coordinated a five-year study on sediment treatment technologies, the goal of which was to examine alternative methods to address and manage contaminated sediments in New York/New Jersey Harbor. A particular focus of U.S. EPA Region 2 work was to evaluate treatment technologies that both decontaminate sediments and produce a marketable final product. This study has resulted in a completed pilot-scale demonstration: a sediment washing process whereby a manufactured topsoil and bricks are produced as marketable end-products. Two additional thermal treatment demonstrations are planned for 2002/2003: a process that produces a blended cement product; and a process that produces a lightweight aggregate product (Stern et al., 1998; Jones et al., 2001).

Utilizing the information generated by U.S. EPA Region 2 in its New York/New Jersey Harbor decontamination program and in an effort to identify treatment technologies with a unit cost (dollars per cubic yard) of less than one hundred dollars (\$100), the Great Lakes National Program Office (GLNPO) has teamed with the Michigan Department of Environmental Quality (MDEQ) for bench-scale testing and evaluation of sediment treatment technologies with beneficial end products (SEG, 1999). MDEQ and GLNPO selected the most promising of these technologies, the thermal destruction Cement-Lock technology, for a pilot-scale demonstration scheduled for 2002. Additionally, GLNPO, U.S. EPA-SITE, the Wisconsin Department of Natural Resources, and Minergy Corporation are coordinating the pilot-scale demonstration and evaluation of Minergy's technology which destroys organic contaminants and encapsulates inorganic contaminants while producing a glass aggregate by-product that can be used for construction fill. Additional demonstrations are planned.

### Science Needs

- Research and development of *ex situ* treatment technologies to search for reasonable possibilities for cost effective treatment of large volumes of sediments (NRC, 1997).
  - Additional full-scale demonstrations of promising treatment options to determine effectiveness of technology on a larger scale and to identify the pathways for contaminant losses and risk associated with contaminant losses during treatment.
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- Significant coordination between U.S. EPA, Army Corps of Engineers (U.S. ACE), and technology vendors to identify cost-effective treatment options and potential end uses of treatment products to offset the cost of treatment.

### **3.6.6 Beneficial Use Technologies**

"Dredged sediments traditionally have been viewed as waste [material]. However, dredged material is often used for beneficial purposes [such as], fill for urban development (such as the construction of National Airport in Washington, DC), beach nourishment, the creation of wetlands and wildlife habitat, for improving farmland [as a soil amendment], as fill for general construction, and for establishing coastal islands where many species of birds nest" (NRC, 1997). The statutory underpinning for the beneficial use of dredged material is provided by the Water Resources Development Act (WRDA) 1992 (P.L. 102-580), which contains provisions for using dredged material for such things as the protection, restoration, and creation of aquatic habitat (NRC, 1997). In addition, both the MPRSA and CWA dredged material disposal regulatory programs help foster beneficial uses by requiring consideration of alternatives (such as beneficial use) to dredged material disposal.

Most beneficial use projects completed to date have used "clean" dredged material, but the National Research Council (1997) contains an extensive list of completed beneficial use projects that used both "clean" and "contaminated" dredged materials. The NRC document also contains references to numerous scientific studies to assess the effectiveness of these beneficial use projects and to determine if there were any environmental impacts from the contaminants associated with the dredged sediments. U.S. ACE, GLNPO, and associated state and local organizations have coordinated on several beneficial use pilot projects within the Great Lakes watershed (mined land reclamation and construction fill projects in Duluth, Minnesota, top soil creation at Toledo, Ohio, Milwaukee, Wisconsin, and Green Bay, Wisconsin). Additionally, the Michigan DEQ realized significant cost saving on a sediment remediation project for Newburgh Lake when the dredged sediments were used as daily cover at a nearby landfill (GLNPO, 2000).

Although there is significant information on research studies and pilot- and full-scale demonstrations of beneficial use, most of the reuse projects are isolated, one-time studies and are not consistently incorporated into long-term management strategies on dredge material management. This is unfortunate since increases in beneficial use could conserve valuable disposal space at Confined Disposal Facilities (CDFs) and landfills.

### **Science Needs**

- Development of technical guidelines for the beneficial use of dredged material, similar to the guidelines for the use of biosolids.
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- Literature review and analysis of beneficial use projects and studies to determine the associated environmental impacts.

### 3.6.7 Disposal Options

The National Research Council (1997) contains an excellent discussion of disposal options for contaminated sediments and a figure for visualizing each alternative. The three major options for contaminated sediment disposal include:

- Landfilling - the placement of sediments into a licensed solid waste facility.
- Confined Disposal Facilities (CDFs) - placement of sediments into a diked in-water, near-shore, or land-based facility specifically designed for containing sediments.
- Contained Aquatic Disposal (CAD) - controlled, open-water placement of contaminated material followed by covering (capping) with clean material. (NRC, 1997).

Both CDFs and landfills have a long history of use, and the state of research and study of these facilities is fairly well advanced. In contrast, fewer actual case studies exist for CAD projects, and therefore, there exists only a limited amount of research on this disposal option. Sumeri (1984) and Truitt (1986) document the results of a CAD project in the Duwamish Waterway in Seattle, Washington (NRC, 1997). In 1992, U.S. EPA and U.S. ACE published a document describing techniques for evaluating releases resulting for various disposal options (U.S. EPA/U.S. ACE, 1992).

### Science Needs

- Improved methods for evaluation of potential release pathways for each disposal option.
- Literature review and evaluation of releases for current disposal facilities, particularly CDFs.
- Improved design criteria for designing and building CADs.
- Investigation of long-term effectiveness and releases for each disposal alternative.
- Better models to predict loss of contaminants via volatilization.

### 3.6.8 Key Recommendations for Sediment Remediation

- E.1 Collect the necessary data and develop guidance for determining the conditions under which natural recovery can be considered a suitable remedial option. Such guidance would include: measurement protocols to assess the relative contribution of the various mechanisms for chemical releases from bed sediments (e.g., advection, bioturbation, diffusion, and resuspension), including mass transport of contaminants by large storm events; methodologies to quantify the uncertainties associated with natural recovery; and
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- development of accepted measuring protocols to determine *in situ* chemical fluxes from sediments. (ORD, OERR, U.S. EPA Regions, GLNPO)
- E.2 Develop performance evaluations of various cap designs and cap placement methods and conduct post-cap monitoring to document performance. Continue to monitor ongoing capping projects to monitor performance (e.g., Boston Harbor, Eagle Harbor, Grasse River). (ORD, U.S. EPA Regions, GLNPO)
- E.3 Encourage and promote the development and demonstration of *in-situ* technologies. (ORD, GLNPO)
- E.4 Using the data provided in recommendation E.1, develop a white paper evaluating the short-term impacts from dredging relative to natural processes and human activities (e.g., resuspension from storm events, boat scour, wave action and anchor drag). (OERR, U.S. EPA Regions)
- E.5 Support the demonstration of cost-effective *ex-situ* treatment technologies and identification of potential beneficial uses of treatment products. (ORD, GLNPO, U.S. EPA Regions)

### 3.7 Baseline, Remediation, and Post-Remediation Monitoring

A sediment monitoring program is required for all types of sediment remedies, both during remedy implementation and over the long-term to ensure that all sediment risk and exposure pathways at a site have been adequately managed by the remedy. Long-term monitoring should continue until all remedial action objectives have been met. In some instances, this may take many decades. A sediment monitoring program encompasses baseline monitoring, monitoring during remedial action implementation, and post-remediation, or long-term monitoring.

Baseline monitoring encompasses the monitoring of those indicators of environmental change (i.e., fish or other biota, sediment chemistry, pore water chemistry, toxicity testing, and benthic community structure) which is conducted prior to the initiation of the remedial action. It is typically conducted during the remedial investigation or site characterization stage. Baseline monitoring should be consistent with the planned long-term or post-remediation monitoring, and to provide a baseline for comparison with the post-remediation monitoring data in order to detect and evaluate environmental trends.

In contrast, post-remediation, or long-term, monitoring is initiated once the remedial action is completed. It involves multiple measurements made over time to assess the success of the remedy in meeting remedial performance goals. The data are used to evaluate the long-term effectiveness of the selected remedial action in protecting human health and the environment, engineering/construction performance and structural integrity of any containment or stabilization structures, the recovery of areas impacted by the remedial action, and the success of mitigation projects built to offset environmental impacts caused by the remedial action; the data can also be

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used to evaluate restoration of the ecosystem. Post-remediation monitoring typically consists of the monitoring of fish or other biota, toxicity testing, and benthic community structure evaluations.

Monitoring during implementation of the remedial action is used to evaluate the short-term effects of the conductance of the remedial action, whether the remedial action project meets design requirements, whether clean-up levels are met, and whether other remedial action objectives are met. In some cases where the implementation of the remedial action spans a significant length of time, the length of time of monitoring during implementation may span several years, if not decades. Natural recovery sites and large dredging projects encompassing millions of cubic yards of sediment are examples of sites where such monitoring may run for decades. Monitoring during remedial action implementation may contain some of the same indicators, but will likely include monitoring of others such as turbidity, dissolved oxygen, sediment chemistry, water chemistry, and air monitoring.

Monitoring is a standard component at a contaminated sediment project, beginning prior to the site investigation when project managers are trying to determine whether there is a problem, and running through post-remediation monitoring. These various types of monitoring programs are being implemented at a number of contaminated sediment sites, and plans are in place to initiate monitoring at others. A few examples of sites where post-remediation monitoring is underway or planned to be initiated are:

1. Cannelton Industries Superfund site on the St. Mary's River, Michigan.
2. Black River, Ohio.
3. River Raisin (Ford Outfalls Superfund removal action site), Michigan.
4. Manistique River and Harbor, Michigan (Superfund removal action site).
5. LCP Superfund site in Brunswick, Georgia.

Monitoring during remedy implementation is underway on the Pine River, Michigan (Velsicol Superfund site). The Sediment Inventory may be referred to for additional information.

**Figure 3-2.**

**Examples of Other Science Activities Related to Monitoring**

- FIELDs software tools have been developed to support the monitoring of remedy implementation and remediation effectiveness (U.S. EPA Region 5 Superfund).
- A Contaminated Sediments Monitoring Workshop will be held.
- Development of monitoring guidance and fact sheets (OSWER and regions), targeted for completion over 2002/2004.
- Development of tools to be used in monitoring (ORD/OW).

Questions arise regarding the short-term impacts and long-term effectiveness of dredging, capping and other *in situ* remedies. A look at sediment sites across the nation shows inconsistencies in the kinds of monitoring performed. Impediments to the implementation of monitoring may be due to limited knowledge on how to develop and implement monitoring plans.

There is an ongoing debate regarding the short-term impacts and long-term effectiveness of dredging and capping remedies, with some claiming that dredging (and possibly capping) cause greater harm through destruction of habitat and release of contaminants. Others argue that while there are short-term impacts, they can be minimized through technology and operational and other controls, and that these remedies will prove to be more protective over the long-term because of the permanent removal of the contaminants or through limitations on bioavailability. Other questions include: Will dredging or capping result in newly created or increased direct toxicity to biota from increases in dissolved or suspended contaminant concentrations in the water column? Will they result in an increase in the bioavailability of contaminants and increased tissue concentrations in fish and other biota? How long does it take for the habitat of a dredged or capped area to become suitable for aquatic life and for re-colonization to take place? Will caps provide attractive habitat for desirable biota, or will they attract less desirable organisms and non-native communities? Information from the monitoring of both remedy implementation and post-remediation is necessary in order to address and resolve these issues.

### Science Needs

The NRC Report (2001a) recommends that “[l]ong-term monitoring and evaluation of [...] contaminated sediment sites should be conducted to evaluate the effectiveness of the management approach and to ensure adequate, continuous protection of humans and the environment.” This is consistent with the issues discussed above - more and better monitoring data are needed. To ensure that such data are collected, guidance and information with regard to available protocols and tests are needed for the remediation project manager’s reference. In addition, to ensure that such monitoring is implemented, a cross-program policy may also be needed. Such a policy may direct the programs and offices to ensure that monitoring is included as a component of remedial alternatives in the Feasibility Study and Record of Decision, and included in settlements with Potentially Responsible Parties (PRPs). For cleanups funded with Federal dollars, sufficient funds would need to be included to cover the cost of the monitoring, or agreements made with state or Federal partners to conduct such monitoring.

Some specific areas that need to be addressed include: an evaluation of the existing protocols and tests performed to identify those which are appropriate for monitoring and any additional needs. For example, U.S. EPA's Office of Water has published protocols for sampling and analysis of fish and shellfish in order to determine human health risks associated with tissue contaminants (U.S. EPA, 2000c). U.S. EPA has also published guidance on collection, storage,

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and manipulation of sediments (U.S. EPA, 2001b), and existing Agency protocols are available for dredged material testing and assessment (U.S. EPA, 1998c and 1991a). These protocols are available for use in monitoring contaminated sediment sites. However, monitoring guidance needs to be developed to provide remediation project managers with a consistent approach to developing monitoring plans and implementing such monitoring. Monitoring guidance should also address how monitoring plans are developed, what protocols and tests are available for use with recommendations for the use for each, how to develop indicators and measures, how to evaluate monitoring data, minimum Quality Assurance/Quality Control (QA/QC) protocols, and specifics regarding which biota and which media should be used for specific situations (i.e., number of, species, and age of fish for bioaccumulative chemicals of concern).

Monitoring data should also be made available to provide information for decision-making at other sediment sites. Please refer to Section 3.9 for additional details with regard to monitoring data management and exchange.

### **3.7.1 Key Recommendations for Baseline, Remediation, and Post-Remediation Monitoring**

- F.1 Develop monitoring guidance fact sheets for baseline, remediation, and post-remediation monitoring, and monitoring during remedy implementation. (ORD, OERR, U.S. EPA Regions, OW)
- F.2 Conduct training and hold workshops for project managers regarding monitoring of contaminated sediment sites. (OERR, ORD, U.S. EPA Regions)

### **3.8 Risk Communication and Community Involvement**

The National Research Council's report, *A Risk-Management Strategy for PCB-Contaminated Sediments* (NRC, 2001a) highlighted the many benefits of involving communities in the cleanup process. "Participation makes the process more democratic, lends legitimacy to the process, educates and empowers the affected communities, and generally leads to decisions that are more accepted by the community (Fiorino, 1990; Folk, 1991; NRC, 1996). The affected community members can contribute essential community-based knowledge, information, and insight that is often lacking in expert-driven risk processes (Ashford and Rest, 1999). Community involvement can also assist in dealing with perceptions of risk and helping community members to understand the differences between types and degrees of risk." Although the benefits of early, active, and continuous community involvement have been widely recognized by U.S. EPA and others, the NRC found that there still remains much progress that needs to be made to more effectively involve communities.

U.S. EPA's two major programs with responsibilities for protecting and cleaning-up contaminated sediments, Superfund and the Office of Water, have both expanded efforts to more

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greatly involve communities in their programs. For example, the Superfund program published a report identifying useful lessons that were learned on how to provide communities greater involvement (U.S. EPA, 1999b). Superfund has developed a number of general guidance documents and tools for use at Superfund sites. *Risk Assessment Guidance for Superfund (RAGS): Volume 1 - Human Health Evaluation Manual. Supplement to Part A: Community Involvement in Superfund Risk Assessments* (U.S. EPA, 1999c) explains how Superfund staff and community members can work together especially during the risk assessment. A video, *Superfund Risk Assessment - What It's All About and How You Can Help*, describes (in lay terms) the Superfund risk assessment process and how communities can help (U.S. EPA, 1999d). Other fact sheets and Community Advisory Group Toolkits have been developed (U.S. EPA, 1998a, 1995b, 1999b, and 1996b). Additionally, the Office of Water's National Fish and Wildlife Contamination Program is developing an updated (second) edition of its *Guidance for Assessing Chemical Contaminant Data for Use in Fish Advisories, Volume IV: Risk Communication* (U.S. EPA, 1995a). This new edition, expected to be completed in Spring 2003, will provide greater emphasis on ensuring that risk communication is culturally appropriate for diverse communities and that all communities should be involved early and throughout the program.

Risk communication provides the means for communities to have a greater role in the evaluation and decision-making process. Risk communication research develops the methods, models, and tools for U.S. EPA to more effectively reach out to communities, earn their trust, and build an effective working partnership. This partnership will allow communities to become more fully engaged in the entire cleanup process – not just as passive listeners, but as important decision-makers. The NRC (2001b) report recognized that U.S. EPA's community involvement program has been advocating greater involvement of affected communities into the cleanup process.

An important component of risk communication and community involvement is ensuring that all the technical information provided to the communities is understandable. Too often communities are either inundated with too much extraneous information that cannot be understood, or they are presented with summaries that contain too little data. Research is needed on both how to effectively extract the appropriate amount of information and determine the best vehicles (e.g., formal presentations, newsletters, informal meetings, videos, infomercials, web sites) for presenting the data to communities. In addition to developing more effective tools for the sender of messages, research is needed to develop better listening skills for all the receivers of messages.

Communities have first-hand knowledge of the site and their own activities (such as catching and consuming fish) that would be very helpful to U.S. EPA's evaluation of the site and its possible impacts on nearby communities. The development of site-specific exposure factors

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based on the measurements of the habits of the local community could reduce reliance on the use of national default assumptions that may not reflect local habits or conditions.

Communities at contaminated sediment sites are diverse and often have conflicting interests that are hard to articulate and quantify. Measurement methods that might be suitable include public opinion survey instruments, randomly selected focus groups, and computer-based methods such as “virtual” town meetings. This is particularly important for sediment sites because they can cover large geographic areas.

Because the effectiveness of risk communication and community involvement are rarely measured in application, there is considerable disagreement about the effectiveness of current public participation activities. Measuring the performance of existing tools and newly developed tools would focus improvements in necessary areas.

### Science Needs

- Develop better methods and tools to measure the preferences of individuals, sub-populations, and communities throughout the entire sediment cleanup process.
- Develop more effective methods and tools to describe, summarize, and present complex technical data to communities.
- Develop better methods and tools to extract and utilize community-based knowledge.
- Develop ways to determine how various societal and cultural values and practices are impacted by contaminated sediments or cleanup activities. For example, the inability of native tribes to harvest fish and then barter them for other valuables is a cultural impact that is not often considered.
- Develop community outreach methods and tools that can be applied to large geographic sites with multiple diverse communities. Because some contaminated sediment sites, especially river sites, can span tens or even hundreds of miles, they present difficult challenges to community involvement staff.
- Develop and apply methods and tools that measure the effectiveness of environmental public participation programs.

#### **3.8.1 Key Recommendations for Risk Communication and Community Involvement**

- G.1 Establish a research program on risk communication and community involvement focusing on developing better methods, models, and tools. (ORD, OERR, U.S. EPA Regions)
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### 3.9 Information Management and Exchange Activities

Information, or data, management is a key component of the characterization, assessment, and monitoring activities conducted at contaminated sediment sites. A data management system provides one point of access for all data and simplifies assessment, QA/QC evaluation, modeling, mapping, querying, trends analysis and other activities that may be conducted using the data. Information communication and exchange are critical components of a contaminated sediment project and would be simplified by the establishment of a quality data management system. Outreach and information-sharing with the public is key to not only their understanding of the ecological and health risks associated with a site, but also of the possible solutions to address those risks. An informed public would be better able to contribute to the decision-making process in a knowledgeable manner.

Some examples of the types of information/data management activities that are underway are shown in Figure 3-3.

**Figure 3-3.**

**Types of Information/Data Management Activities Currently Underway**

- GLNPO's sediment database.
- OW's Sediment Inventory.
- OERR's Superfund sediment sites database.
- U.S. EPA Region 5/GLNPO Sediment Information Management System

Other information communication and exchange activities are identified in Figure 3-4.

**Figure 3-4.**

**Information Communication and Exchange Activities**

- Sediment Network (OW).
- Superfund Sediment Forum (OERR).
- Participation on external fora such as the National Sediment Dialogue and Great Lakes and other regional Dredging Teams.
- Great Lakes sediment web page (GLNPO).
- Public Outreach Tools: Sediment pamphlet and poster (OW) and a dredging video (OERR).
- U.S. EPA Region 5/GLNPO Sediment Information Management System (SIMS).
- U.S. EPA Region 5 Superfund's Fully Integrated Environmental Locational Decision Support (FIELDS) system.
- U.S. EPA Region 5's sediment web page.

## Science Needs

Environmental data need to be appropriately housed in data management systems. Such data management systems should be consistent and able to link across the regions and offices. Environmental information regarding these sites needs to be placed onto regional contaminated sediment web sites which are updated on a regular basis. They should link across the regions so that information on sites in other regions is available to the viewer. Networks should be formed so that information about contaminated sediment sites and issues can be exchanged and discussed. Workshops and other fora should be held periodically for a range of audiences as additional means of communicating and exchanging information, and increasing the science knowledge of stakeholders and others.

There is a need for more timely information exchange, improved access to environmental information and data, both internally across the Agency and with external stakeholders and other interested parties. One of the recommendations in the National Research Council Report (2001b) is that there be “early, active, and continuous involvement of all affected parties and communities as partners.” One of the many keys to the success of such involvement is the availability of, and access to, environmental information and data about the site(s) of concern. In addition, stakeholders may also need some basic science knowledge (or someone to explain it) so as to be able to comprehend what the data and information means and be better able to contribute to the decision-making process in an informative manner.

### **3.9.1 Key Recommendations for Information Management and Exchange Activities**

- H.1 Establish regional sediment data management systems which can link the regions and program offices with each other and with the National Sediment Inventory. (U.S. EPA Regions, OW, OSWER, GLNPO)
  - H.2 Standardize the sediment site data collection/reporting format. Establish minimum protocols for quality assurance/quality control (QA/QC). (OEI, OW OSWER, U.S. EPA Regions)
  - H.3 Develop national and regional contaminated sediment sites web sites for sharing information. (U.S. EPA Regions, OW, OSWER, GLNPO)
  - H.4 Re-establish and expand the Office of Water-sponsored Sediment Network by including more regional representation. (OERR, OW, U.S. EPA Regions)
  - H.5 Promote communication and coordination of science and research among Federal agencies. (ORD, OSWER, OW, U.S. EPA Regions, NOAA, U.S. Navy, U.S. ACE, USGS, U.S. FWS)
  - H.6 Promote the exchange of scientific information via scientific fora (i.e., workshops, journals, and meetings). (CSMC, OW, OSWER, U.S. EPA Regions, GLNPO)
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## **4. LONG-RANGE SCIENCE STRATEGY**

### **4.1 Introduction**

There are many scientific uncertainties associated with assessing and managing contaminated sediments. Multiple offices and regions have overlapping science needs; some have individual, program-specific requirements. Realistically, it will take a long-term program to develop, implement, and verify the science. Planning across all U.S. EPA organizations, with recognition of important work being conducted by other organizations, is essential to advancing the science and managing risks from contaminated sediments in the most cost-effective ways.

### **4.2 Key Recommendations**

In the presentation of each major topic in Chapter Three, the authors discussed the state of the science and science needs. Science needs were developed to provide guidance on what scientific tasks are needed to address the topics' key scientific question. These needs address a wide array of data gaps, method development, guidance requirements, and communication issues.

The Contaminated Sediments Science Plan science needs for the major topics were focused through the generation of key recommendations. In the development of key recommendations for the Contaminated Sediments Science Plan, the Workgroup members reviewed Chapter Three science needs for each major topic. As each major topic was discussed, science needs were evaluated for their high priority, critical nature to address data gaps in the topic, ability to reduce uncertainty, and identification of state-of-the-science guidance or tools. Key recommendations for each major topic were agreed to by the Workgroup members using the evaluation criteria, professional judgement, comment or input from Agency review, and a group consensus process. The Workgroup did not constrain the recommendations to fit within available resources. Instead, the recommendations are a comprehensive list that U.S. EPA organizations can consider when balancing resource allocations across competing high priority needs.

The thirty-three (33) key recommendations described in this section address the contaminated sediment issues and data gaps, as well as areas for better coordination of contaminated sediment science activities, including research, across the Agency that are identified as highest priority by the Contaminated Sediments Science Plan Workgroup and have undergone cross-Agency review. The recommendations are listed by science area and include: sediment site characterization; exposure assessment research; health effects research; ecological

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effects research; sediment remediation; baseline, remediation, and post-remediation monitoring; risk communication and community involvement; and information management and exchange activities.

#### **4.2.1 Sediment Site Characterization**

Accurate sediment site characterization is of great importance to scientists, risk managers, and others involved in the decision-making process. Because of the complexity of chemical fate and transport processes in sediment, water, and biota, many factors can affect the kinds and magnitude of impacts that contaminated sediment has on the environment. These factors include hydrology, the physical and chemical characteristics of the sediment, the types of contaminants present and their associated human health or ecological effects, and synergistic or antagonistic effects of contaminants. Better tools and methods for analysis of physical and chemical parameters, biological testing, evaluation of ecological effects, and sediment sampling will result in sound science to support decision-making.

##### *Physical Parameters*

#### **A.1 Conduct a workshop to develop a consistent approach to collecting sediment physical property data for use in evaluating sediment stability.**

A workshop is needed to identify research necessary to develop better, faster, and more cost-effective methods for high resolution determination of physical sediment parameters. Such methods are needed for evaluating remedial options (e.g., natural attenuation, capping, or dredging). When evaluating remedial options, risk managers must obtain information on key physical sediment parameters including the erosional and depositional properties of sites to be remediated. High resolution spatial data are needed to characterize freshwater sites where sediment is often heterogeneous. Improved spatial resolution of field survey data will enable more accurate determination of the volume or mass of contaminated sediment. It is recommended that U.S. EPA consult with U.S. Geological Survey, U.S. Army Corps of Engineers, and U.S. Navy on their progress in developing these techniques. An improved understanding of the relationships between geomorphological and physical sediment parameters and contaminant transport, fate, and effects will enable decision-makers to more effectively evaluate site management alternatives.

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*Chemical Parameters***A.2 Develop more sensitive, low-cost laboratory methods for detecting sediment contaminants, and real-time or near real-time chemical sensors for use in the field.**

Interferences encountered as part of the sediment matrix, particularly in samples from heavily contaminated areas, may limit the ability of available methods to detect or quantify some analytes. More sensitive, low-cost methods are needed to detect sediment contaminants and the chemical parameters that control bioavailability of contaminants such as PCBs, dioxin, PAHs, metals, and pesticides. Real-time or near real-time sensors are also needed to provide both point measurements and long-term, time-series observations of sediment contaminants of concern. Real-time chemical sensors will enable better, faster, and more cost-effective site assessment and the immediate targeting of hot spots for potential remediation.

**A.3 Develop U.S. EPA approved methods with lower detection limits for analysis of bioaccumulative contaminants of concern in fish tissue.**

Many chemical contaminants can persist for relatively long periods of time in sediments where bottom-dwelling animals can accumulate and pass them up the food chain to fish and wildlife. Therefore, improved methods are needed for analysis of chemical contaminants such as PCBs, dioxin, metals and pesticides in fish tissue. U.S. EPA has published interim procedures for sampling and analysis of priority pollutants in fish tissue (U.S. EPA, 1981). However, official U.S. EPA-approved methods are available only for the analysis of low parts-per-billion concentrations of some metals in fish and shellfish tissues (U.S. EPA, 1991b). Although U.S. EPA-approved methods for many analytes have not been published, states and regions have developed specific analytical methods for various target analytes (U.S. EPA, 2000d).

**A.4 Develop methods for analyzing emerging endocrine disruptors, including alkylphenol ethoxylates (APEs) and their metabolites.**

Present methods for analyzing emerging endocrine disrupting chemicals are inadequate. Methods for analyzing endocrine disruptors, including APEs and their metabolites, should be developed to support regulatory decision-making.

**4.2.2 Exposure Assessment****B.1 Develop a tiered framework for assessing food web exposures.**

The National Research Council (2001a) recommended a tiered approach to risk assessment for PCB-contaminated sediment sites that would work well for any sediment contaminated by bioaccumulative compounds. The screening tier would apply conservative

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assumptions and rely on existing data in the literature to easily distinguish sediments that do not pose an unacceptable risk from those that may. The middle tier would use a combination of some site-specific data and interpretive tools to produce a more refined assessment of the level of risk. At many sites, this approach would be sufficient to determine whether or not remediation was warranted and would provide some insight into the potential benefits of alternative remedies. The highest tier of exposure assessment would rely heavily on site-specific data and would include model tailoring and model calibration to site conditions. This most sophisticated assessment would be applied only at selected sites where the combination of site complexity, resource values, affected party interests, and potential costs warrant a detailed investigation of existing and potential future exposures.

ORD's research and program applications are presently focused at the middle tier; funding is being sought to expand the research to the lower and higher tiers. This recommendation is to provide program guidance for implementing the screening tier and to conduct research and model validation for the highest tier.

## **B.2 Develop guidance and identify pilots for improving coordination between TMDL and remedial programs in waterways with contaminated sediments.**

In many of the country's water bodies, there are multiple legal authorities to address both existing contaminated sediments and continued contaminant loading. Pilot projects need to be developed to identify the most effective ways to integrate environmental management to control sources and achieve water quality goals. Integrated management models need to be improved and communicated within U.S. EPA and to partners in state programs. Results of the TMDL pilot projects in waterways with contaminated sediments should be made available to the states as potential models for the development of complex TMDLs involving multiple toxic pollutants and media (i.e., water, sediment, and fish tissue).

## **B.3 Develop and advise on the use of the most valid contaminant fate and transport models that allow prediction of exposures in the future.**

Numerous models exist for contaminant fate and transport, including both public domain and proprietary codes. Some models have not been peer-reviewed in the open literature and there are very few long-term data sets that can be used to judge predictive capability. The existing public domain and commercial models need to be evaluated to determine their mechanistic and mathematical foundations and robustness, and to determine the extent to which they are accepted by the scientific community. One or more models need to be further developed to improve any weaknesses determined from the evaluation; the Office of Research and Development (ORD) has begun this work. The models need to be validated with high quality data sets, which will be developed via other recommendations in this plan.

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The fate and transport models also need to link with models that predict direct and food web exposures for the purpose of assessing risks and comparing remediation alternatives. The bioavailability of the contaminants within portions of the system has to be considered to provide input from the transport models to the exposure/effects models.

#### **B.4 Develop a consistent approach to applying sediment stability data in transport modeling.**

Current approaches to evaluating sediment stability in transport modeling vary across the Agency and the larger stakeholder community. While a single model is probably not appropriate for all sites, a consistent approach is needed to ensure that important factors are being considered. Data sets developed by the regions and other organizations can help identify the key factors that the transport models need to include for realistic predictions. In addition, a workshop was held in January 2002 to conduct a comparative evaluation of the models for hydrogeological conditions in terms of the reliability of predictions.

### **4.2.3 Human Health Effects and Risk Assessment**

#### **C.1 Develop guidance for characterizing human health risks on a PCB congener basis.**

Improved methods are needed to assess the risks associated with exposure to aged PCBs in sediment. For example, although it is recognized that measurement of PCB Aroclors in sediment can underestimate exposure to PCBs, this method of chemical analysis continues to be used in risk assessments because a toxicity equivalence approach for evaluating PCB congeners has not been fully developed.

#### **C.2 Develop sediment guidelines for bioaccumulative contaminants that are protective of human health via the fish ingestion pathway.**

Contaminant-specific sediment guidelines to protect recreational and subsistence anglers should be developed. This will conserve resources by efficiently eliminating sites or parts of sites and chemicals from further study, and will help focus site investigations on the most important areas. Fish tissue contaminant guidelines have been developed for a range of chemicals (U.S. EPA, 2000a), but corresponding levels of contaminants in sediments must be developed. Guidelines for bioaccumulative contaminants such as DDT and metabolites, PCBs, methyl mercury, dieldrin, and high molecular weight PAHs should be developed.

#### **C.3 Refine methods for estimating dermal exposures and risk.**

Although the greatest human health risk is generally from ingestion of contaminated fish, there is a need to develop better methods, models, and exposure factors that will enable risk

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assessors to estimate the exposure from direct skin contact with contaminated sediments. Research is needed to determine the amount of sediment that might come into contact with the skin from various activities. Research is also needed to develop a model that accurately predicts how much of the sediment-borne contaminants actually crosses the dermal barrier and is available to cause a toxicological effect. Current dermal absorption models are either water or soil-based and it is not clear which might be more applicable for sediments.

**C.4 Evaluate the toxicity and reproductive effects of newly recognized contaminants, such as alkylphenol ethoxylates (APEs) and other endocrine disruptors and their metabolites on human health.**

Additional long-term toxicity data are needed on APEs and other similar chemicals to further understand their long-term effects on reproductive and other systems.

**4.2.4 Ecological Effects and Risk Assessment**

**D.1 Develop sediment guidelines to protect wildlife from food chain effects.**

Sediment quality guidelines are needed to protect piscivorous birds and wildlife from food chain effects. The contaminants should be bioaccumulative chemicals such as PCB, DDT, and methyl mercury. This effort would include a consistent method for estimating the site-specific bioavailability of contaminants.

**D.2 Develop additional tools for characterizing ecological risks.**

Benthic community studies and single-species sediment toxicity tests are often used to evaluate the baseline risks to ecological receptors and the risks after remediation. Additional methods to assess long-term risks, especially for persistent bioaccumulating compounds, should be developed and validated. This includes the use of smaller, short-lived fish to predict the long-term food chain effects on game fish, and the use of molecular or genetic indicators to predict endocrine disruptor impacts.

**D.3 Develop guidance on how to interpret ecological sediment toxicity studies (lab or *in situ* caged studies); and how to interpret the significance of the results in relation to site populations and communities.**

A more consistent process is needed to allow risk managers to determine: 1) if the observed or predicted adverse effects on a structural or functional component of the site's ecosystem is of sufficient type, magnitude, areal extent, and duration that irreversible effects have occurred or are likely to occur; and 2) if these effects appear to exceed the normal changes in the structural or functional components typical of unimpacted ecosystems. Interpretive

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guidance for ecological sediment toxicity studies, and the significance of the results to site populations and communities needs to be developed to better evaluate the need to protect an ecological resource. For bioassay endpoints such as survival, growth, and reproduction, population models should be developed to provide further insight into interpretation of test results.

**D.4 Acquire data and develop criteria to use in balancing the long-term benefits from remedial dredging vs. the shorter term adverse effects on ecological receptors and their habitats.**

The process of remedial dredging can result in a short-term increase in the water column level of suspended or dissolved contaminants as well as the removal of existing biota and a severe disruption of their habitats. Quantitative or qualitative criteria are needed that can be used to determine when there is more benefit to the existing ecosystem from leaving the contamination in place and preserving the impacted biota and habitat versus a destructive remedy that removes the contamination but causes short-term impacts. This analysis would also include predicting recovery times for all scenarios considered.

It is recommended that U.S. EPA collaborate with appropriate Federal agencies to study the short- and long-term impacts from environmental dredging. At least two locations should be monitored thoroughly to quantitatively determine all contaminant losses during remedial dredging. At these projects, all currently accepted management practices (e.g., silt curtains, covered clamshell buckets, state-of-the-art cutter heads for hydraulic dredging) will be employed to ensure minimal resuspension. All losses quantified as part of the remedial dredging operation would then have to be measured against overall benefits to the site by evaluating ecological benefits for at least a ten-year horizon. Such a study could go far towards resolving the argument that short-term negative impacts from remedial dredging outweigh long-term ecological benefits.

*Biological Testing (bioassays and bioaccumulation tests)*

**D.5 Conduct field and laboratory studies to further validate and improve chemical-specific sediment quality guidelines.**

Chemical-specific sediment quality guidelines have been developed by U.S. EPA for use in contaminated sediment assessment, prevention, and remediation programs. Field validation studies have been conducted on some of these guidelines for these uses. However, additional field validation studies and laboratory tests using a range of species should be conducted to further validate the guidelines and understand contaminant exposure routes. Work is also needed to develop mixtures guidelines for sediment contaminants.

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**D.6 Continue developing and refining sediment toxicity testing methods.**

Although a number of sediment toxicity test methods have been standardized, protocols using new freshwater, marine, and estuarine test species must be developed to provide sensitive tests representing a greater range of species and habitat types. The currently available *Leptocheirus plumulosus* chronic test protocol uses an Atlantic Coast species, which may not adequately represent the sensitivity of species from Pacific Ocean systems. Chronic, sublethal test protocols are needed for marine species present in the Pacific, such as the amphipod *Grandidierella japonica*. Additional freshwater test protocols are needed for burrowing species. Field-based test methods (e.g., *in situ* test methods) are needed to assess the biological effects of contaminated sediments. Some of the currently available test protocols are expensive and difficult to run. Test protocols should be simplified to reduce costs, and interpretive guidance for sublethal test methods should be developed. A number of marine and estuarine test protocols for amphipod species have been developed. Consideration should be given to developing additional methods for species other than amphipods.

**D.7 Develop whole sediment toxicity identification evaluation procedures for a wide range of chemicals.**

Sediment contaminants often occur in mixtures. Whole sediment toxicity identification evaluation methods are needed in order to determine which contaminants cause observed toxicity. Currently available toxicity identification evaluation methods are capable of characterizing the toxicity of a sediment only by identifying classes of toxic contaminants (e.g., metals or organic toxicants). Additional work is needed to improve the method so that individual chemical contaminants can be identified. In addition, work is needed to conduct field validation studies supporting the method.

**4.2.5 Sediment Remediation***Natural Recovery/Bioremediation*

**E.1 Collect the necessary data and develop guidance for determining the conditions under which natural recovery can be considered a suitable remedial option. Such guidance would include: measurement protocols to assess the relative contribution of the various mechanisms for chemical releases from bed sediments (e.g., advection, bioturbation, diffusion, and resuspension), including mass transport of contaminants by large storm events; methodologies to quantify the uncertainties associated with natural recovery; and development of accepted measuring protocols to determine *in situ* chemical fluxes from sediments.**

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When selecting a remedial option for a particular site, it is critical to determine the methods by which contaminants are lost or transported, and which mechanisms play significant roles. In many situations large storm events will be the largest mechanism to move contaminants from a particular hot spot. In other more quiescent settings, such processes as advection, diffusion and bioturbation may predominate. In many systems, the predominant method of contaminant loss will vary over the season, with resuspension by storm events predominating in spring and other mechanisms dominant over the rest of the year. Knowing the relative contributions of these mechanisms is critical in determining whether natural recovery or capping are the most appropriate remedial options for a site.

It is thus recommended that research be continued and increased for examining the relative contributions of the various mechanisms for contaminant release from sediments.

#### *In Situ Capping*

### **E.2 Develop performance evaluations of various cap designs and cap placement methods and conduct post-cap monitoring to document performance. Continue to monitor ongoing capping projects to monitor performance (e.g., Boston Harbor, Eagle Harbor, Grasse River).**

The design and installation of conventional sediment caps is well understood; however, the long-term effectiveness of this remedial alternative has not been well researched. In addition, many entities are now beginning to discuss more complex cap designs, including the use of biological treatment.

With capping becoming a management option being recommended at more sites, it is critical that evaluations be conducted to document its effectiveness. Capping demonstration projects should be promoted and long-term monitoring be implemented to document cap performance. All mechanisms of loss must be quantified during such a study including diffusion, advection, bioturbation, and storm events.

#### *In Situ Treatment*

### **E.3 Encourage and promote the development and demonstration of *in-situ* technologies.**

*In situ* technologies, if proven effective, would be the most efficient means for remediating contaminated sediment sites. Such a technology would avoid the problems and arguments of whether or not removing sediments via dredging does more harm than good. It would also navigate around all the difficulties associated with finding a disposal site.

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U.S. EPA should actively identify and work with any vendors who have a viable technology for treating contaminants *in situ*. Demonstration projects examining *in situ* technologies should be conducted and evaluated to determine their efficacy. The testing of one such technology, electrogeochemical oxidation, is currently being applied at a number of sites around the country. As part of these projects, the process will be extensively monitored to evaluate its performance in treating sediments.

#### *Dredging/Removal*

**E.4 Using the data provided in recommendation E.1, develop a white paper evaluating the short-term impacts from dredging relative to natural processes and human activities (e.g., resuspension from storm events, boat scour, wave action and anchor drag).**

Large storm events are known to move large volumes of sediment and their associated contaminants. Any study examining the impacts from dredging must also be examined in relation to all mechanisms of contaminant loss ongoing at a particular site. All contaminant losses that would naturally occur at a site including resuspension from storm events, advection, diffusion, and bioturbation, must be taken into account when evaluating dredging impacts. Only when the net losses from these processes are known can the impacts associated with dredging be adequately evaluated.

#### *Ex Situ Treatment Technologies*

**E.5 Support the demonstration of cost-effective *ex situ* treatment technologies and identification of potential beneficial uses of treatment products.**

Much work on *ex situ* treatment has been conducted by both U.S. EPA Region 2 and The Great Lakes National Program Office. A number of demonstrations have been successfully completed to date, and others are planned. We are now confident that tools do exist to decontaminate sediments. It is apparent, however, that to make treatment a viable, cost effective option, a marketable end use product must be developed, particularly at sites that have large volumes of contaminated sediments.

Partnerships need to be developed with industry to conduct joint demonstrations and examine all options for making treatment cost effective and a viable alternative to landfilling.

#### **4.2.6 Baseline, Remediation, and Post-remediation Monitoring**

There is an ongoing national debate regarding the short-term impacts and long-term effectiveness of dredging and capping remedies, with some claiming that dredging and capping

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cause greater harm through destruction of habitat and release of contaminants. Others argue that while there are short-term impacts, they can be minimized through technology and operational and other controls, and that these remedies will prove to be more protective over the long-term because of the permanent removal of the contaminants or through limitations on bioavailability. A review of sediment sites across the nation show a lack of or limited monitoring data with which to answer these questions and resolve the debate. In addition, monitoring data needs to be made available to inform decision-making at contaminated sediment sites.

The NRC Report (2001a) recommends that “[l]ong-term monitoring and evaluation of [...] contaminated sediment sites should be conducted to evaluate the effectiveness of the management approach and to ensure adequate, continuous protection of humans and the environment.” This is consistent with the issues discussed above; more and better monitoring data are needed of both remedy implementation and post-remediation in order to address and resolve these issues.

The impediments to monitoring include limited knowledge on how to develop monitoring plans, including the types of measurements to be performed, how often monitoring should occur and over how long a period of time, and how they should be implemented.

The following key recommendations are made to address these issues.

#### **F.1 Develop monitoring guidance fact sheets for baseline, remediation, and post-remediation monitoring, and monitoring during remedy implementation.**

To ensure that monitoring data will be collected, guidance and a compendium of available protocols and tests are needed for the project manager’s reference. Some specific areas that need to be addressed, including an evaluation of the existing protocols and tests, should be performed in order to identify those which are appropriate for monitoring and what additional needs there may be. Monitoring guidance needs to be developed to provide project managers with a consistent approach to developing monitoring plans and implementing such monitoring. Such guidance should also address how monitoring plans are developed, what protocols and tests are available for use with recommendations for the use for each, how to develop indicators and measures, how to evaluate monitoring data, minimum Quality Assurance/Quality Control (QA/QC) protocols, and specifics regarding which biota and which media should be used for specific situations should be used (i.e., number of, species, and age of fish for bioaccumulative chemicals of concern).

To meet this need, the Contaminated Sediments Science Plan recommends that the Office of Emergency and Remedial Response (OERR), with support from the other program offices and regions, initiate the development of monitoring guidance fact sheets in FY02/03 with a goal of

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finalizing them by the end of FY03. It is suggested that a workgroup be established with representation from across the program offices and regions to take on this task.

In addition, a review/evaluation should be conducted of the available protocols and tests in order to identify those most appropriate for specific types of monitoring and to identify any gaps which may need to be filled. This information would be compiled into a compendium and be available as a reference document for the guidance and fact sheets.

## **F.2 Conduct training and hold workshops for project managers regarding monitoring of contaminated sediment sites.**

Training is needed to teach project managers how to develop and implement monitoring plans, and evaluate the resulting data with regard to remedy implementation and performance. Workshops or other fora are needed to share monitoring information and remedy performance.

To begin to meet these needs, a two-day Monitoring Workshop should be held under the suggested lead(s) of ORD and OERR. The target audience would be U.S. EPA scientists and project managers of contaminated sediment sites. An advisory group should be formed with participation from the various program and regional offices to plan the workshop.

The CSSP also recommends that additional sessions be held periodically (whether they be training workshops or brown bags for the purpose of teaching how to conduct monitoring or prepare monitoring plans, or fora for the purpose of sharing experiences and results), and at various levels (i.e., regional, national, U.S. EPA only, or U.S. EPA plus external parties). The leads for planning such sessions may be at the national or regional level. Use of existing fora is encouraged, such as the annual National Association of Remedial Project Managers (NARPM) meeting, or the National Superfund Site Assessment Conference. At the regional level, a program office may take the lead to sponsor a brown bag on monitoring. The timing of such regional sessions will be left to the discretion of the regions. It is also recommended that a national workshop be held in conjunction with the completion of the draft monitoring guidance, under the sponsorship of OERR, ORD, and OW.

### **4.2.7 Risk Communication and Community Involvement**

Advances in the science of risk communication would result in much more meaningful community involvement in the contaminated sediments cleanup process. The methods, models, and tools produced by this research would allow U.S. EPA to more effectively reach out to communities, earn their trust, and build effective working partnerships – partnerships that empower communities to become more fully engaged in the entire cleanup decision-making process. To accomplish this, the following recommendation is made:

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**G.1 Establish a research program on risk communication and community involvement focusing on developing better methods, models, and tools.**

There are many potential benefits to be gained by conducting research in this area. The Office of Research and Development should take the lead in developing a solicitation package to conduct research in one or more of these project areas.

**4.2.8 Information Management and Exchange Activities**

Information, or data, management is a key component of the characterization, assessment, and monitoring activities conducted at contaminated sediment sites. A data management system provides one point of access for all data and simplifies assessment, QA/QC evaluation, modeling, mapping, querying, trends analysis and other activities that may be conducted using the data. Information communication and exchange are critical components of a contaminated sediment project and would be simplified by the establishment of a quality data management system. Outreach and information sharing with the public is key to their understanding of the ecological and health risks associated with a site and of the possible solutions to address them.

There is a need for more timely information exchange and improved access to environmental information and data, both internally across the Agency and with external stakeholders and other interested parties. A recommendation in the National Research Council Report (2001b) is that there be “early, active, and continuous involvement of all affected parties and communities as partners.” One of the many keys to the success of such involvement is the availability of, and access to, environmental information and data about the site(s) of concern. In addition, stakeholders may also need some basic science knowledge (or someone to explain it) so as to be able to comprehend what the data and information mean and be better able to contribute to the decision-making process in an informative manner.

To meet these needs, the following recommendations are made.

**H.1 Establish regional sediment data management systems which can link the regions and program offices with each other and with the National Sediment Inventory.**

There is a need for more timely information exchange regarding contaminated sediment sites, and improved access to environmental information and data. This will allow for improved decision-making in addition to being able to learn from the experiences of others. The two key impediments or issues, in addition to the lack of sediment data management systems in general, are the lack of consistent formats among such systems, and a lack of accessibility between regional systems and the national program offices.

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To address these issues, it is recommended that the regional information management programs should take the lead for ensuring regional sediment data management systems are established, and to provide the technical support that may be needed. The regional program offices will need to work together to establish roles and responsibilities on how the data management systems will be set up and maintained. The Office of Environmental Information (OEI) would also have a key role in this activity. The existing data management systems such as U.S. EPA's STORage and RETrieval database (STORET) should be evaluated to see if any are able to meet the needs identified here. It is suggested that a workshop be held for the regions and program offices to share information on existing data management systems and how this recommendation might best be implemented. This work should be initiated in FY02.

## **H.2 Standardize the sediment site data collection/reporting format. Establish minimum protocols for quality assurance/quality control (QA/QC).**

Because data are collected both by various U.S. EPA programs and offices and by other agencies, collection and reporting formats and QA/QC protocols vary. This leads to difficulties in sharing information across programs/offices and between U.S. EPA and other agencies.

To address these issues, it is recommended that U.S. EPA's Environmental Information Office, with OW and OSWER, take the lead in developing standardized formats and identifying minimum QA/QC protocols. The regions, state environmental agencies, and other Federal agencies, as appropriate, should be involved. It is recommended that a workshop be held in the near future to address these issues, with the protocols being developed from the workshop.

## **H.3 Develop national and regional contaminated sediment sites web sites for sharing information.**

To also meet the need for more timely information exchange regarding contaminated sediment sites, the CSSP recommends that a national sediment web site be established. The proposed sediment web site under consideration in OW should be considered for use as a centralized web site to meet this need. OW is suggested to take the lead, with support from OEI, OERR, and other offices and regions as appropriate. Web sites developed by the regions and programs should link with the national sediment web site. GLNPO, OW, OERR, and some of the regions are developing or have developed contaminated sediment web sites containing information on sediment sites, and also provide links to guidance and other information regarding the contaminated sediment problem. Where they do not exist, and are found to be needed, it is recommended that regional remedial and water programs, working with their regional information management programs, jointly develop contaminated sediment sites web sites. It is recommended that these web sites be in place in 2003.

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#### **H.4 Re-establish and expand the Office of Water-sponsored Sediment Network by including more regional representation.**

The CSSP recommends that the Sediment Network be re-established in 2002 under the co-lead of OW and OERR. Key representatives from appropriate national and regional program offices should be the targeted participants. The suggested purpose of the Network would be to resolve issues and to share information (each representative would then share the information through their own organizations). Regular teleconferences should be scheduled. It is also suggested that an OW/OSWER memorandum be prepared and sent to the program offices and regional offices announcing the Sediment Network and inviting their participation.

A sediment list server is also recommended as an additional means of sharing information and resolving issues for a larger audience. Responsibility for maintenance of such a list server should be jointly shared between OW and OSWER.

#### **H.5 Promote communication and coordination of science and research among Federal agencies.**

Many other Federal agencies and departments also sponsor research on many of the same sediment research topics. The CSSP recommends that coordination and communication of science and research among Federal agencies be promoted in order to avoid duplication of efforts, encourage partnering between researchers working on similar projects, and facilitate the timely sharing of interim and final results. Agencies that might participate include U.S. EPA, NOAA, U.S. Navy, U.S. Army Corps of Engineers, U.S. Geological Survey, and U.S. Fish and Wildlife Service.

#### **H.6 Promote the exchange of scientific information via scientific fora (i.e., workshops, journals, and meetings).**

The CSSP recommends that national and regional program offices encourage their managers and staff to share scientific information via workshops, conferences, publication in journals, and presentations. Other options for sharing scientific information should be explored at the regional level.

### **4.3 Recommended Approaches to Implement Strategy**

In order to achieve the goals of the Contaminated Sediments Science Plan (CSSP), its implementation should result in the development of tools and scientific methods, enhancement of agency communication and coordination, and development of effective scientific information that will support risk management decisions on contaminated sediments problems.

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The CSSP recommends that the Contaminated Sediment Management Committee (CSMC), comprised of Office and Division directors, has the responsibility for ensuring the implementation of the key recommendations in the CSSP through their role as a forum for cross-agency coordination and collaboration on science activities in contaminated sediments. It is recommended that the CSMC include all U.S. EPA offices and regions that play a key role in contaminated sediment issues and implementation of the recommendations of the CSSP.

It is recommended that the CSMC do this by holding an annual meeting of U.S. EPA offices and regions. This meeting should serve to identify the status of science activities on the key recommendations, to communicate recent results, and to plan future activities. To accomplish this, the following tasks should be completed at the annual meeting:

- **Reviewing science activities**

The lead U.S. EPA offices and regions should present to the CSMC the current science activities they are conducting pertaining to research topics and key recommendations identified in the CSSP. In addition, they should identify those additional science activities, based on the key recommendations in the CSSP, that they would implement should sufficient resources become available. This information sharing will serve to initiate closer coordination of science activities related to contaminated sediments across U.S. EPA.

- **Implementing science activities**

Lead U.S. EPA offices and regions who agree to carry out the recommended science activities should ensure that these activities are considered within their annual planning, budgeting, and accountability process, and are implemented when resources are committed. It is recommended that for each recommendation, a brief one-page description be developed (or updated) which includes the following information: title, key partners, actions underway, actions planned over next two years, products expected by (date), and primary contact(s). Please refer to Appendix B for an example. The one-page recommendation descriptions and a report out on the status of the implementation of the science activities would be provided at the annual meetings. The CSMC would then determine whether progress toward the goals is being made and, if necessary, recommend adjustments to science activities to meet the key recommendations.

- **Identifying areas where science partnerships are needed**

The CSMC should recommend to U.S. EPA offices and regions where scientific collaboration within the Agency, as well as with other Federal agencies, would be beneficial. These partnerships will hopefully speed the accomplishment of key recommendations.

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- **Coordinating with U.S. EPA offices and regions**  
The CSMC should contact the lead U.S. EPA office or region identified as a suggested critical partner from Table 4-1 for each key recommendation to understand how they intend to implement science activities for the recommendations.
- **Identifying unfunded activities**  
Resource needs for unfunded or underfunded tasks should be identified. The CSMC should discuss unfunded science areas and communicate these to the appropriate science planning staff within U.S. EPA offices and regions in order to identify the appropriate resources to address them.
- **Updating the CSSP**  
Periodic reviews of the state of the science on contaminated sediments, a gaps analysis, and updating of the CSSP are recommended every five years.

Table 4-1 lists the key recommendations by topic area, the time frame for implementation, and suggested critical partners. Although recommendations are roughly divided into two time frames, immediate and longer term, some of the recommendations could be viewed as continuing needs.

**Table 4-1. Summary of Key Recommendations, Time Frame for Implementation, and Suggested Critical Partners**

Recommendations
<p><b>A. Sediment Site Characterization</b></p> <p><i>Immediate Time Frame</i></p> <p>A.1 Conduct a workshop to develop a consistent approach to collecting sediment physical property data for use in evaluating sediment stability. (OERR, ORD, U.S. EPA Regions)</p> <p><i>Longer Time Frame</i></p> <p>A.2 Develop more sensitive, low-cost laboratory methods for detecting sediment contaminants, and real-time or near real-time chemical sensors for use in the field. (ORD, OERR, GLNPO)</p> <p>A.3 Develop U.S. EPA-approved methods with lower detection limits for analysis of bioaccumulative contaminants of concern in fish tissue. (ORD, OERR, OW, U.S. EPA Regions)</p> <p>A.4 Develop methods for analyzing emerging endocrine disruptors, including alkylphenol ethoxylates (APEs) and their metabolites. (ORD)</p>

**B. Exposure Assessment***Immediate Time Frame*

- B.1 Develop a tiered framework for assessing direct and food web exposures. (ORD, OW, OERR, U.S. EPA Regions)
- B.2 Develop guidance and identify pilots for improving coordination between TMDL and remedial programs in waterways with contaminated sediments. (OW, OSWER, U.S. EPA Regions)
- B.3 Develop and advise on the use of the most valid contaminant fate and transport models that allow prediction of site-specific exposures in the future. (ORD, OERR, OW, U.S. EPA Regions)
- B.4 Develop a consistent approach to applying sediment stability data in transport modeling. (ORD, OERR, OW, U.S. EPA Regions)

**C. Human Health Effects and Risk Assessment***Immediate Time Frame*

- C.1 Develop guidance for characterizing human health risks on a PCB congener basis. (ORD, OERR, U.S. EPA Regions)
- C.2 Develop sediment guidelines for bioaccumulative contaminants that are protective of human health via the fish ingestion pathway. (ORD, OERR, OW, U.S. EPA Regions)

*Longer Time Frame*

- C.3 Refine methods for estimating dermal exposures and risk. (ORD, OERR, U.S. EPA Regions)
- C.4 Evaluate the toxicity and reproductive effects of newly recognized contaminants, such as alkylphenol ethoxylates (APEs) and other endocrine disruptors and their metabolites on human health. (ORD)

**D. Ecological Effects and Risk Assessment***Immediate Time Frame*

- D.1 Develop sediment guidelines to protect wildlife from food chain effects. (ORD, OERR, OW, U.S. EPA Regions)
- D.3 Develop guidance on how to interpret ecological sediment toxicity studies (lab or *in situ* caged studies) and how to interpret the significance of the results to site populations and communities. (OW, ORD, OERR, U.S. EPA Regions)
- D.4 Acquire data and develop criteria to use in balancing the long-term benefits from dredging vs. the shorter term effects on ecological receptors and their habitats. (ORD, OERR, U.S. EPA Regions)

- D.6 Continue developing and refining sediment toxicity testing methods. (ORD, OW, U.S. EPA Regions)
- D.7 Develop whole sediment toxicity identification evaluation procedures for a wide range of chemicals. (ORD, OW)

*Longer Time Frame*

- D.2 Develop additional tools for characterizing ecological risks. (ORD, U.S. EPA Regions, OW)
- D.5 Conduct field and laboratory studies to further validate and improve chemical-specific sediment quality guidelines. (OW, ORD)

**E. Sediment Remediation***Immediate Time Frame*

- E.1 Collect the necessary data and develop guidance for determining the conditions under which natural recovery can be considered a suitable remedial option. Such guidance would include: measurement protocols to assess the relative contribution of the various mechanisms for chemical releases from bed sediments (e.g., advection, bioturbation, diffusion, and resuspension), including mass transport of contaminants by large storm events; methodologies to quantify the uncertainties associated with natural recovery; and development of accepted measuring protocols to determine *in situ* chemical fluxes from sediments. (ORD, OERR, U.S. EPA Regions, GLNPO)
- E.2 Develop performance evaluations of various cap designs and cap placement methods and conduct post-cap monitoring to document performance. Continue to monitor ongoing capping projects to monitor performance (e.g., Boston Harbor, Eagle Harbor, Grasse River). (ORD, U.S. EPA Regions, GLNPO)
- E.4 Using the data provided in recommendation E.1, develop a white paper evaluating the short-term impacts from dredging relative to natural processes and human activities (e.g., resuspension from storm events, boat scour, wave action, and anchor drag). (OERR, U.S. EPA Regions)

*Longer Time Frame*

- E.3 Encourage and promote the development and demonstration of *in-situ* technologies. (ORD, GLNPO)
- E.5 Support the demonstration of cost-effective *ex-situ* treatment technologies and identification of potential beneficial uses of treatment products. (ORD, GLNPO, U.S. EPA Regions)

**F. Baseline, Remediation, and Post-remediation Monitoring***Immediate Time Frame*

- F.1 Develop monitoring guidance fact sheets for baseline, remediation, and post-remediation monitoring, and monitoring during remedy implementation. (ORD, OERR, U.S. EPA Regions, OW)
- F.2 Conduct training and hold workshops for project managers regarding monitoring of contaminated sediment sites. (OERR, ORD, U.S. EPA Regions)

**G. Risk Communication and Community Involvement***Immediate Time Frame*

- G.1 Establish a research program on risk communication and community involvement focusing on developing better methods, models, and tools. (ORD, OERR, U.S. EPA Regions)

**H. Information Management and Exchange Activities***Immediate Time Frame*

- H.1 Establish regional sediment data management systems which can link the regions and program offices with each other and with the National Sediment Inventory. (U.S. EPA Regions, OW, OSWER, GLNPO)
- H.3 Develop national and regional contaminated sediment sites web sites for sharing information. (U.S. EPA Regions, OW, OSWER, GLNPO)
- H.4 Re-establish and expand the Office of Water-sponsored Sediment Network by including more regional representation. (OERR, OW, U.S. EPA Regions)
- H.5 Promote communication and coordination of science and research among Federal agencies. (ORD, OSWER, OW, U.S. EPA Regions, NOAA, U.S. Navy, U.S. ACE, USGS, U.S. FWS)
- H.6 Promote the exchange of scientific information via scientific fora (i.e., workshops, journals, and meetings). (CSMC, OW, OSWER, U.S. EPA Regions, GLNPO)

*Longer Time Frame*

- H.2 Standardize the sediment site data collection/reporting format. Establish minimum protocols for quality assurance/quality control (QA/QC). (OEI, OW OSWER, U.S. EPA Regions)

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